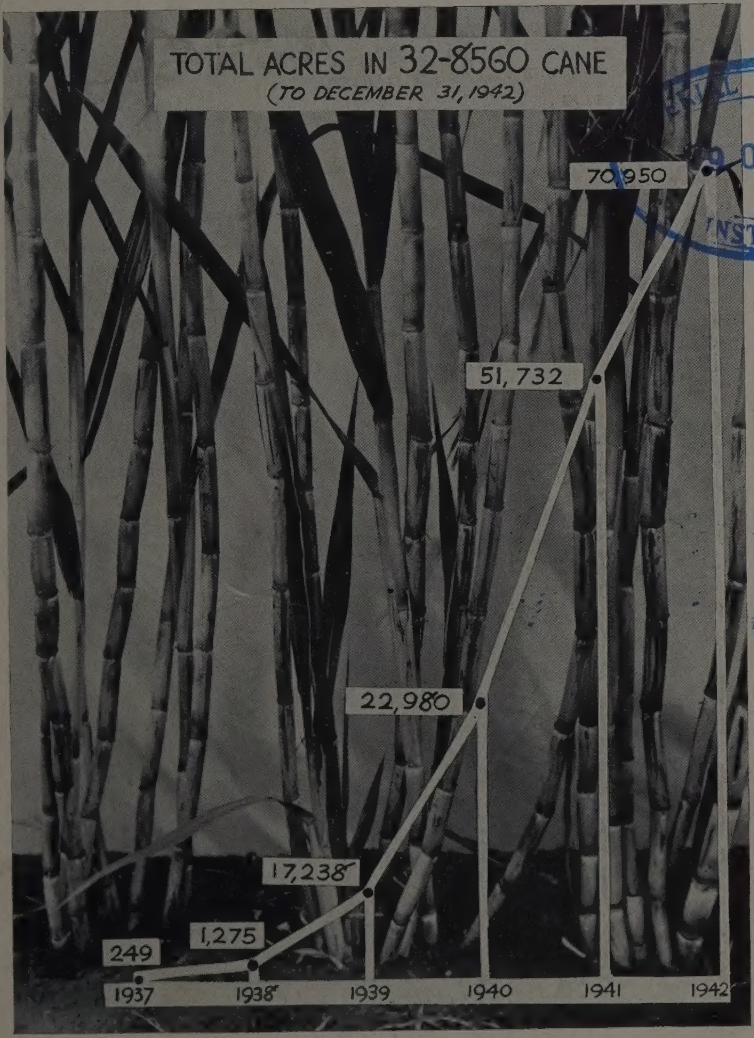
VOLUME XLVII NUMBER 3

THE HAWAIIAN PLANTERS' RECORD



THIRD QUARTER 1943

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THE HAWAIIAN PLANTERS' RECORD

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Replication: The Safeguard for Uncontrolled Variation

By R. J. Borden

Only by a knowledge of the nature and extent of the expected variations in his basic materials can the investigator of sugar cane problems hope to plan his research to identify and separate the chance effects from his purposely applied treatment effects, and thereby arrive at reliable conclusions. Hence we have brought together herein only a few examples, taken from actual data which have been previously recorded, which show some of the variations found in many of the soil and plant analyses which are commonly made; also common variations found in studies of the crop composition and its growth rates, in crusher juice analyses, in cane yields, cane quality, and sugar yields. Then, without discussing reasons for these variations, and without laying down the principles which should govern the selection of duplicate samples but assuming the use of a sound sampling technique and accurate analytical work, and as far as possible avoiding the usage of mathematical expressions and formula, we have sought in this presentation an opportunity to make the investigator aware of the absolute necessity for replication, if his results are to have a real meaning and be truly evaluated for the benefits of the industry.

Quantitative data secured from measurements in biological studies are characterized by great variations, in contrast to the small variations which are found in the more precise sciences of chemistry, physics, and mathematics. Thus the investigator who studies the sugar cane crop must be fully aware of the variations which are involved in his basic material or he is apt to make erroneous assumptions and likely to draw false conclusions, as a result of overlooking the principles and limitations of sampling; for he must make use of samples and from his measurements on these, make sound inferences with respect to the crop from which his samples were taken.

To awaken a fuller appreciation of the extent and nature of some of the uncontrolled or normal variations which are found, we offer the following illustrations. These have been selected as examples, not necessarily of average or typical condi-

tions but rather of variations actually found in measurements which have been made on what had appeared to the eye to be from relatively uniform materials.

Variations in Soil

One of the contributory factors to differences in cane yields and their composition is the variation that exists within the soil of the area where the crop was grown. Thus even under the same environment, with similar influences from sunshine, temperature, wind, and rainfall, we find soil variations of considerable magnitude, and

SOIL VARIATIONS

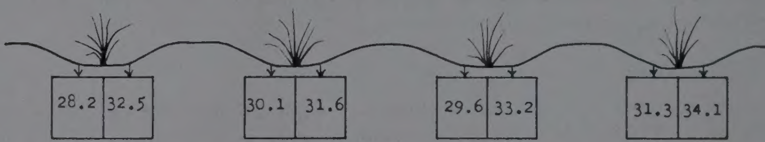

Fig. 1. Percentages of soil moisture at the 6" to 24" depth on opposite sides of 4 adjacent rows of cane.

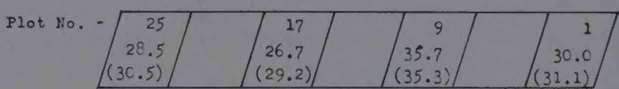

Fig. 2. Percentages of soil moisture in the upper (and second) 12" soil zones of 4 "check" plots.

Fig. 4. Moisture equivalents in adjacent cane rows at 12" deep.

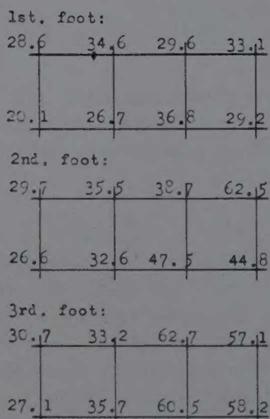

Fig. 3. Moisture equivalent values at points 300' apart. Borings from 1st., 2nd., and 3rd. foot of soil

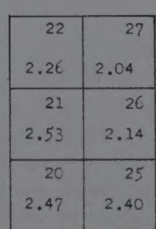

Fig. 5. Per cent total organic matter in upper 12" of soil.

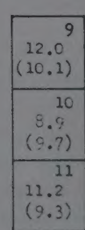

Fig. 6. C/N ratios in upper (and second) foot of soil.

we know that they exert their differential effects upon the growth and composition of a sugar cane crop.

1. Soil Moisture Percentages:

Differences as great as 4.3 per cent in soil moisture were recorded within pairs of single auger-bored soil samples taken from the 6-inch–24-inch soil depth on opposite sides of actively growing POJ 2878 cane in adjacent rows of Makiki Field 2 (Fig. 1).

Five days after irrigating the 8 "control" plots in Waipio Experiment 104 I, duplicate soil samples each made up from auger borings taken at two points within each one-tenth acre plot, from both the upper foot and second foot of soil, had variations in their average moisture content between 26.7 and 35.7 per cent (Fig. 2).

2. Moisture Equivalents:

Determinations of moisture equivalents of single soil borings taken at the intersections of 300-foot coordinates in Olowalu Field 27 show variations quite characteristic of alluvial soils. In this case the differences are quite large, especially in the samples from the second and third foot of soil (Fig. 3).

Four of the individual soil borings taken 12 inches deep under two adjacent cane rows from Waimanalo Field 11 had moisture equivalents between 41.4 and 37.0 per cent (Fig. 4).

3. Total Organic Matter:

The percentages of total organic matter found in samples made up from 10 borings each, taken from the upper foot of soil in 61 plots of Waipio Field L, varied from 1.54 to 2.72. The variation in a small block of six adjacent plots occupying an area of less than three-fourths of an acre ranged between 2.04 and 2.53 per cent—a difference which amounts to nearly 1500 pounds per acre (Fig. 5).

4. Carbon-nitrogen Ratios:

The surface foot of soil from each of three adjacent plots, embracing an area of only one-fifth of an acre in Waipio Field L, was found to have a carbon-nitrogen ratio of 11.2, 8.9, and 12.0; the complementary C/N ratios in the second foot of these soils were 9.3, 9.7, and 10.1 respectively (Fig. 6).

5. Water-soluble Nitrogen:

Composited soil-bored samples from an irrigated area of growing cane in Kawaihapai Field 1A taken from the upper and the second 12-inch soil layers, both within the row and in the adjoining row-middles, showed a variation in their nitrate nitrogen content which is nicely illustrated in Fig 7. A somewhat different picture, but one still showing a considerable amount of difference in the content of available nitrogen of the upper foot of soil in closely adjoining areas, is shown in Fig 8; here the cane in Grove Farm Field 19A had recently been "hilled up."

Separate "check" plots in Waipio Experiment V, all included within a total area of less than 1½ acres and adequately sampled at the start of a first ratoon crop, were found to have soil differences in their total water-soluble nitrogen varying from 18 to 85 pounds per acre (Fig. 9).

SOIL VARIATIONS

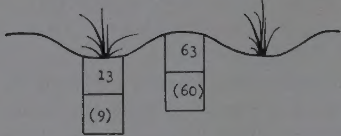

Fig. 7. Pounds of nitrate nitrogen per acre from cane row and adjacent row middle, at 0 - 12" and (12 - 24").

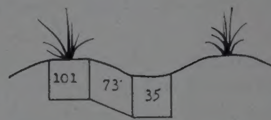

Fig. 8. Pounds per acre of available nitrogen from 3 positions in hilled-up cane.

38		41		21		38		18	
	26		23		18		33		80
85		25		38		38		28	
	26		20		58		33		70

Fig. 9. Pounds per acre of water-soluble nitrogen in soil of "check" plots only (plot size - .038 acre).

30	125	100	100	150
70	85	125	53	100
38	30	70	100	70
30	38	30	85	125

Fig. 10. Pounds of P_2O_5 per acre from borings at 5 x 5 ft. spacings. after plowing.

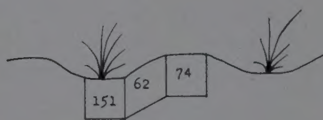

Fig. 11. Pounds P_2O_5 per acre at 3 positions to a depth of 12".

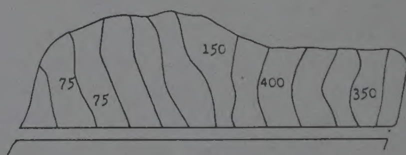

Fig. 12. Pounds of K_2O per acre from 5 sampling stations within a total field area of 21 acres.

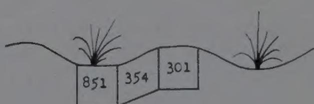

Fig. 13. Pounds of K_2O per acre at 3 positions; cane in the furrow.

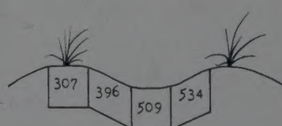

Fig. 14. Pounds of K_2O per acre at 4 positions; cane hilled-up.

6. Available Phosphoric Acid:

Variations in the available phosphate content of continually cropped cane soils are not uncommon. Our example, from single borings made at 5- x 5-foot spacings to a depth of 12 inches in Maui Agricultural Company Field 77, shows a range equivalent to from 30 to 150 pounds P_2O_5 per acre, even after the field had been plowed and prepared for planting (Fig. 10).

Composited auger borings taken to a depth of 12 inches from three positions (with respect to the ratoon cane row) in Lihue Field L26 show a commonly observed condition which is found in ratoon fields, i.e., a higher percentage of available P_2O_5 in the soil *in* the cane row (Fig. 11).

7. Available Potash:

Reliably taken soil samples from each of 5 level-ditch areas of Pioneer Field H1 covering an area of 21 acres, for purposes of identifying the status of available potash for guidance in the potash fertilization for this field, showed a range between 75 and 400 pounds of K_2O per acre (Fig. 12).

Analyses of soil taken to a depth of 12 inches from Grove Farm Field 17 before fertilizing, from several positions with respect to their proximity to the cane growing in the furrow, showed large variations in the available K_2O content, with higher potash being found directly under the cane row (Fig. 13). However, in Paauhau Field 21 hilled-up cane had somewhat less potash directly under the cane row than farther away (Fig. 14). In both of these cases the soil sampling technique was reliable.

Variations in Crop Composition

A crop of sugar cane, especially after it is a year old, consists of a rather complex aggregation of stalks of different ages and conditions. Its composition is constantly changing, with new stalks being added and old stalks disappearing, and seldom is the extent of these changes predictable. Thus the nature of the crop which is finally harvested can be almost anything than that which was expected earlier.

1. Stalk Census at Harvest:

Something of the variable nature of the stalk population harvested from 10 adjacent 35-foot rows of 31–1389 plant cane which had started its growth with a uniform stand of stalks can be seen from the following record of stalk classes made at the harvest of the Makiki Field 19 Blank Test.

STALK CENSUS, *I.E.*, NUMBER OF STALKS*

Classes	Adjacent row numbers									
	12	13	14	15	16	17	18	19	20	21
Sound stalks . . .	186	155	158	144	181	177	175	166	180	186
Dead stalks . . .	3	11	12	36	9	9	25	35	26	9
Suckers	25	5	8	11	21	16	8	16	35	15

* Project A 105—No. 103.

2. Suckers:

The number of suckers with millable cane at harvest is likely to be an extremely variable amount. In Waipio Experiment 108 ATN, suckers with at least 6 feet of millable stalks were counted and weighed in the cane samples taken from some of the "D" plots in October and again in February; their contribution to the total weight of cane harvested varied as indicated below:

SUCKERS AS PER CENT OF TOTAL CANE WEIGHT*

Month	Duplicate plot numbers			
	5	11	32	60
October . . .	9	33	9	33
February . .	14	39	8	37

* Waipio Expt. 108 ATN.

Variations in Growth

1. Elongation:

Those who have studied cane growth and have actually made hundreds of growth measurements are fully aware of the differences in the rates of stalk elongation which apparently similar stalks of cane will often make; those who read the reports which summarize such growth measurements as averages may not always be aware of the extent of these differences in growth which individual stalks of cane make, even under identical external conditions.

From Cornelison's files, we note the following differences in the daily elongation of the first 10 primary stalks of H 109 which he tagged and measured at one growth stage in his studies of cane in the field at Makiki.

PRIMARY STALK ELONGATION (INCHES/DAY)*

Ten duplicate primary stalks of H 109									
No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10
.48	.41	.19	.53	.60	.34	.84	.37	.52	.43

* Data by Cornelison (F.T.G.).

Even when cane is grown under controlled conditions in large pots of the same well-mixed soil and in the same environment, the individual stalks of the same age group will grow at very different rates. Thus primary stalks of POJ 2878 grown in large containers at Makiki showed variations in their daily rates of growth during 4 successive 2-week growth periods as indicated below:

PRIMARY STALK ELONGATION (INCHES/DAY)*

Period: week of	6 duplicate stalks of POJ 2878					
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6
1. July 27 . . .	.29	.64	.57	.86	.79	.46
2. August 10 . .	.21	.71	.39	.82	.21	.36
3. August 24 . .	.36	.36	.75	.53	.79	.50
4. September 8 .	.21	.82	.86	.36	.11	.29

* Project A 105—No. 43.

Both of the preceding examples come from measurements made on primary stalks which were tagged for identification in their early growth period and measured periodically thereafter. Hence they may not truly represent the growth being made by the crop, since the crop will include many stalks of a later growth order, i.e., younger stalks which have a considerably faster growth rate. Thus growth measurements made on stalks representative of the entire crop will show an even greater individual variation. This will be apparent from the following tabulation that was made up from measurements on 100 contiguous stalks of H 109 cane grown at Makiki.

COMPLETE POPULATION STALK ELONGATION (INCHES/DAY)*

Stalks	No. of stalks making daily growth during Aug.-Sept. of Less than .5″	.5 to .99″	1.0 to 1.49″	More than 1.49″	Total no.
All first season . .	5	50	14	0	69
Early second season	0	5	21	5	31

* Project A 105—No. 114.

2. Density of Stand and Weight per Stalk:

Records of the density of the stalk population together with the weights of the stalks therein at harvest show variations which at times are the controlling factors in yield differences obtained. An idea of such variations is given in the following record made from 10 adjacent 40-foot rows of cane from plot 1 in the Waipio Field T Blank Test.

STALKS PER FOOT OF ROW AND AVERAGE WEIGHT PER STALK

Measurement	Duplicate adjacent row numbers 1	2	3	4	5	6	7	8	9	10
Number of stalks/ft. . .	4.9	4.1	3.2	3.9	4.1	3.4	2.4	5.2	2.8	3.7
Weight per stalk (lbs.) .	5.8	7.2	9.3	6.2	6.7	7.0	8.2	6.3	9.1	6.3

Variations in Plant Composition

We are still concerned with pointing out examples of variations in measurements and analyses of duplicated samples taken from the sugar cane crop. We are much more interested in the analysis of the duplicated individual samples than in a duplicate analysis of a composited sample, for much greater variation exists in the sample than in the analytical work. This fact will be better appreciated as we proceed with our examples of variation, many of which are taken from one of our most recent studies in connection with Waipio Experiment 108 ATN.

1. Per Cent Moisture:

From 8 replicated plots of Treatment A in Waipio Experiment 108 ATN we can get an idea of the variation in the percentage of moisture found in representative samples of the total green weight by examining the figures secured from the harvest at 10½ months; they range between 72.7 and 77.3 per cent although they come from carefully taken cane crop samples which are duplicates.

PER CENT MOISTURE IN TOTAL GREEN WEIGHTS*

Duplicate plot numbers 1	8	13	20	27	28	30	37
76.0	77.3	72.7	72.7	75.4	73.4	73.9	74.7

* Waipio Expt. 108 ATN.

Determinations of the per cent moisture in identical samples of carefully selected leaf sheaths taken from leaves of identical physiological age from cane of the 3 "X" plots of this same field test, during its maximum growth period, reveal differences amounting to 3 and 4 per cent in moisture content.

PER CENT MOISTURE IN LEAF SHEATHS*

Duplicate plot nos.	Age of cane (months)			
	8½	9½	10½	11½
17	71.4	69.6	68.6	69.6
26	70.2	73.7	69.7	71.2
31	73.3	71.8	68.8	72.7

* Waipio Expt. 108 ATN.

2. Per Cent Reducing Sugars:

At the age of 14½ months, representative cane samples taken from the 8 replicated plots of Treatment D* showed especially wide variations in their percentages of reducing sugars (dry-weight basis).

PER CENT REDUCING SUGARS IN TOTAL DRY WEIGHTS*

Duplicate plot numbers							
4	5	9	14	19	25	29	36
3.86	7.80	8.59	7.07	7.79	8.04	7.67	10.04

* Waipio Expt. 108 ATN.

3. Per Cent Sucrose:

The 8 duplicate plots of Treatment C* produced a crop of cane which at 17½ months of age varied from 36.6 to 42.9 per cent in the sucrose concentration of its total dry weight.

PER CENT SUCROSE IN TOTAL DRY WEIGHT*

Duplicate plot numbers							
3	6	15	18	22	24	33	35
42.9	40.1	41.3	36.6	42.9	41.5	37.4	40.4

* Waipio Expt. 108 ATN.

4. Per Cent Total Sugars:

At the October harvest from Waipio Experiment 108 ATN the percentages of total sugars that were found in the total dry weight samples harvested from the 8 replicated plots of Treatment A showed considerable variation—between 36.2 and 46.7 per cent.

PER CENT TOTAL SUGARS IN TOTAL DRY WEIGHT*

Duplicate plot numbers							
1	8	13	20	27	28	30	37
41.0	45.0	46.7	40.1	41.4	39.9	36.2	38.3

* Waipio Expt. 108 ATN.

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* Waipio Expt. 108 ATN.

The concentration of total sugars in the sheaths of active leaves taken from 4 plots of Treatment A was quite dissimilar at some of the earlier preharvests from this same experiment.

PER CENT TOTAL SUGARS IN LEAF SHEATHS*

Duplicate plot nos.	Age of cane (months)			
	7½	8½	9½	10½
23	8.32	9.69	7.76	8.44
28	8.62	9.60	12.42	10.25
34	9.06	11.19	12.92	10.97
37	10.32	12.12	12.47	9.53

* Waipio Expt. 108 ATN.

5. Per Cent Nitrogen:

Cane harvested from a 2 x 5 block of 10 adjacent plots in Waipio Field L, all of which had received identical fertilization at the time the samples were taken, had a variable nitrogen composition between limits of .44 and .72 per cent.

PER CENT NITROGEN IN TOTAL DRY WEIGHT*

Duplicate plot numbers									
1	2	5	6	12	13	18	19	23	24
.72	.49	.46	.44	.60	.47	.45	.50	.52	.56

* Waipio Expt. 108 ATN.

Four separate leaf-punch samples, taken from 31–1389 cane in rows 2, 5, 8 and 12 of Makiki Field 19 at 12 months, had a composition of 1.59, 1.44, 1.15, and 1.80 per cent nitrogen respectively, in spite of the fact that all this cane had received identical treatment.

The percentage of nitrogen in leaf-punch samples taken from the 7 replicated "C" plots of Waipio Experiment 109 AN at 11½ months varied from 1.45 to 1.77 even though all 7 plots had received identical nitrogen fertilization.

PER CENT NITROGEN IN LEAF-PUNCH SAMPLES*

Duplicate plot numbers						
41	43	45	48	49	52	53
1.77	1.67	1.67	1.55	1.67	1.45	1.61

* Waipio Expt. 109 AN.

6. Per Cent Chlorophyll in Green Leaves:

Samples of active green-leaf blades, taken from a 2 x 4 block of 8 plots which had been similarly fertilized, showed a range in their chlorophyll content at 5½ months from .075 to .169 per cent.

PER CENT CHLOROPHYLL IN GREEN LEAVES*

Duplicate plot numbers							
23	24	28	29	33	34	36	37
.075	.129	.158	.127	.145	.127	.169	.127

* Waipio Expt. 108 ATN.

7. Per Cent Phosphoric Acid:

An analysis of cane crop samples taken from the H 109 "check" plots of Waipio Experiment 104 I at 10 months showed a difference between the duplicates of as much as 100 per cent in the percentages of phosphate that were found in the total dry-weight samples.

PER CENT P_2O_5 IN TOTAL DRY WEIGHT*

Duplicate plot numbers							
1	8	9	16	17	24	25	32
.050	.080	.100	.053	.070	.085	.070	.050

* Waipio Expt. 104 I.

At the final harvest at 20½ months of the 8 replicated "A" plots in Waipio Experiment 108 ATN, samples of the total dry weight varied in their P_2O_5 concentration from .132 to .219 per cent.

PER CENT P_2O_5 IN TOTAL DRY WEIGHT*

Duplicate plot numbers							
1	8	13	20	27	28	30	37
.157	.162	.164	.219	.132	.177	.183	.177

* Waipio Expt. 108 ATN.

8. Per Cent Potash:

Variations between .63 and 1.23 were recorded for the percentages of K_2O that were found in truly representative samples of the total dry weight harvested from the 8 "D" plots of Waipio Experiment 108 ATN at 20½ months.

PER CENT K_2O IN TOTAL DRY WEIGHT*

Duplicate plot numbers							
4	5	9	14	19	25	29	36
.97	.63	.77	.85	1.23	.87	.73	.72

* Waipio Expt. 108 ATN.

Variation in Crusher Juices

1. Brix, Pol, and Purity:

Individual cane samples of 10 entire stalks each, collected at random within a single "burn" of H 109 cane and crushed separately, showed wide variations in their crusher juice analyses.

BRIX, POL, AND PURITY OF JUICE FROM DUPLICATE CANE SAMPLES*

Measurement	Duplicate sample numbers 95	96	97	98	99
Brix . . .	18.8	20.7	17.6	16.0	16.2
Pol . . .	15.9	18.2	14.0	11.7	12.2
Purity . .	84.1	87.8	79.7	73.4	75.1

* Project A 105—No. 112.

An extent of the variations found in crusher juices from *all* stalks of 31–1389 plant cane harvested from a few adjacent 30-foot rows in the Makiki Field 19 Blank Test is indicated below:

BRIX, POL, AND PURITY OF CRUSHER JUICES*

Measurement	Adjacent row numbers 3	4	5	6	7	8
Brix . . .	18.0	17.0	17.8	17.6	16.2	15.8
Pol . . .	16.4	15.4	15.8	15.7	14.4	13.5
Purity . .	91.1	90.6	88.8	89.2	88.9	85.4

* Project A 105—No. 103.

Single primary stalks of H 109 cane, which were grown separately in small pots of thoroughly mixed Makiki soil and given identical treatment, produced crusher juices with a considerable amount of variation, even under carefully controlled, identical growth conditions.

BRIX, POL, AND PURITY OF CRUSHER JUICES*

Measurement	Duplicate pot numbers 384	389	390	393	397
Brix . . .	21.3	20.0	20.2	19.6	19.0
Pol . . .	20.8	19.0	19.3	17.2	17.8
Purity . .	97.7	95.0	95.5	87.8	93.7

* Project A 105—No. 140.1.

2. Per Cent Glucose:

Evidence that differences in the percentage of glucose found in crusher juices from mature cane may be quite considerable is shown by analyses made from duplicate plots of POJ 36 cane harvested at Manoa.

PER CENT GLUCOSE IN CRUSHER JUICES*

Duplicate plot numbers 3	6	9	12	15	18
.44	.36	.40	.48	.72	.67

* Project A 105—No. 28.

3. Per Cent Nitrogen:

At the July harvest of Waipio Experiment 108 ATN the crusher juices from the 8 replicated plots of Treatment C had a wide variation in their nitrogen content.

PER CENT NITROGEN IN CRUSHER JUICE*

Duplicate plot numbers							
3	6	15	18	22	24	33	35
.017	.024	.025	.012	.024	.019	.034	.018

* Waipio Expt. 108 ATN.

Even though 31–1389 cane was grown in small pots of well-mixed Makiki soil under identical conditions, the percentages of nitrogen in the crusher juices from 4 duplicate pots at harvest were still quite dissimilar.

PER CENT N IN CRUSHER JUICE*

Duplicate pot numbers			
818	819	820	821
.125	.110	.099	.057

* Project A 105—No. 126.

We could cite many examples of this sort from our pot studies—instances where crusher juices from duplicate pots differed by more than 100 per cent.

4. Per Cent P_2O_5:

Six replicated pots of 31–1389 cane grown on Ranch 1 soil without phosphate fertilization produced cane with a different crusher juice concentration of phosphoric acid.

PER CENT P_2O_5 IN JUICE*

Duplicate pot numbers					
610	611	612	613	614	615
.060	.045	.096	.056	.044	.080

* Project A 105—No. 122.

Duplicate pots of Manoa soil and also of Makiki soil produced POJ 2878 cane with crusher juice contents of P_2O_5 which were quite different within each soil group.

PER CENT P_2O_5 IN CRUSHER JUICES*

Manoa soil duplicates		
No. 51	No. 59	No. 67
.029	.052	.036

Makiki soil duplicates		
No. 78	No. 88	No. 96
.120	.096	.072

* Project A 105—No. 43.

5. Per Cent K_2O:

The percentages of potash in crusher juices from 31–1389 cane grown in 5 duplicate pots of Manoa soil showed considerable variation also.

PER CENT K_2O IN JUICE*

Duplicate pot numbers				
135	136	137	138	139
.08	.08	.14	.26	.11

* Project A 105—No. 98.

6. Per Cent N, P_2O_5, and K_2O:

This final example is offered to show that even when only 2 primary stalks were allowed *to grow in the same pot* of Manoa soil, some individual inherent characteristic resulted in crusher juice concentration differences between these two stalks.

PER CENT N, P_2O_5, K_2O IN CRUSHER JUICES OF 31–1389 CANES*

Nutrient	Stalk No.	Duplicate pot numbers 1293	1294	1322	1327	1329
N . . .	1	.016	.028	.028	.031	.043
N . . .	2	.024	.040	.016	.019	.019
P_2O_5 . .	1	.016	.010	.014	.016	.017
P_2O_5 . .	2	.018	.014	.010	.014	.012
K_2O . .	1	.04	.04	.05	.05	.05
K_2O . .	2	.06	.07	.03	.03	.03

* Project A 105—No. 131.

Variation in Cane Yields and Quality

Many of the variations we have just discussed are responsible for the differences so commonly found in actual yields of cane and its quality as harvested from separate units of uniformly treated field areas. In previous discussions we have emphasized these important differences which can occur even on relatively uniform field areas, but it will do no harm to cite again a few examples to complete our picture of normal variations.

Cane Yields:

In Fig. 15 we show the yields of cane (TCA) which were harvested from 8 separate but contiguous .05-acre plots within each of three 5-row strips of Yellow Caledonia plant cane in Pepeekeo Field 20. They tell their own story of the yield variation which existed on what appeared to be a perfectly uniform part of this field, and a careful examination of this area after the yields were recorded revealed no apparent reason for such large differences as were actually found between plot numbers 4 and 5, or 6 and 7, or 10 and 11, or 17 and 18, or 21 and 22.

If further evidence of this nature is desired, another example can be shown by using the cane yields from a block of .05-acre plots from the most uniform-appearing acre of cane in the 1938 Blank Test in Hakalau Field 2A. These are shown in Fig. 16, and though not as "spotty" as the yields shown in Fig. 15, they do illustrate the range in cane yields which we often find even within a small uniform field area.

Variability in yields of cane harvested from duplicate treatments to cane grown in containers of well-mixed soil is a factor for concern for those who use a con-

VARIATIONS IN CANE YIELDS AND QUALITY

1 99	2 97	3 91	4 85	5 66	6 94	7 68	8 67
9 106	10 101	11 82	12 84	13 88	14 70	15 80	16 74
17 86	18 62	19 76	20 76	21 62	22 98	23 89	24 84

Fig. 15. Yields of cane, as tons per acre, from 87' sections of 5-row "X" plots in Pepeekeo Field 20 Blank Test.

64 98	65 93	66 86	67 81	68 92	69 83
34 80	35 81	36 72	37 70	38 66	39 61
4 92	5 83	6 78	7 77	8 82	9 84

Fig. 16. Variations in T.C.A. from a uniform block of .05-acre plots in 1938 Hakalau Blank Test.

2 10.2	15 10.8	28 8.2	41 8.1
3 9.0	16 9.1	29 9.7	42 9.5
4 12.1	17 10.3	30 9.5	43 9.4
5 10.9	18 10.8	31 9.0	44 9.0
6 11.5	19 10.2	32 9.0	45 9.9

Fig. 17. Variation in Y % C in block of 20 plots of 1929 Hakalau Blank Test.

9 9.4	10 9.7	11 8.1	12 8.3	13 8:5	14 9.8	15 10.8	16 11.0

Fig. 18. Yield % cane variations in 8 sections of a 12-row strip of cane from Grove Farm Expt. 89 V.

trolled "pot-test" technique in their investigations. Thus we have found such yield differences as the following from separate but duplicate small containers cropped under identical conditions.

POUNDS OF CANE HARVESTED FROM POTS HOLDING 5 KILOS OF SOIL*

Duplicate pot numbers							
75	80	83	85	88	91	94	96
2.33	2.69	2.77	3.75	2.88	3.73	2.75	1.97

* Project A 105—No. 140.1.

Even with the use of somewhat larger containers, variations in weights, from duplicated pots of cane are apt to be wide.

POUNDS OF CANE HARVESTED FROM POTS HOLDING 8 CUBIC FEET OF SOIL*

Duplicate pot numbers								
2	6	10	17	21	25	105	109	113
43	74	57	67	77	70	49	69	60

* Project A 105—No. 123.

Cane Quality:

Differences in cane quality, though perhaps not usually as great as differences in cane yields, are nevertheless found, even when there seems to be no easily apparent difference in the cane itself. Thus in the 1929 Hakalau Blank Test, a block of twenty .05-acre plots located on the most uniform-appearing part of the test area produced Yellow Caledonia cane with quality differences indicated by yield per cent cane values between 8.1 and 12.1 (Fig. 17). All of these plots had received identical treatment. At Grove Farm (Expt. 89V) a uniform 12-row strip of 31–1389 cane, divided into eight .13-acre sections at harvest had variations between 8.1 and 11.0 per cent in its yield per cent cane (Fig. 18).

Cane quality variations are also found even when a controlled pot-culture technique is used by the investigator. Thus 31–1389 cane harvested from 4 large concrete tubs (capacity 500 pounds, soil), all of which had similar exposures to weather factors and identical treatment, showed a considerable amount of difference in their cane quality, even though they differed less than 10 per cent in their cane weights.

YIELD PER CENT CANE*

Duplicate pot numbers			
27	31	35	39
15.4	13.7	11.9	14.3

* Project A 105—No. 33.

With smaller containers holding about 70 pounds of well-mixed soil and carefully handled to provide identical growth conditions for the cane therein, variations in the yield per cent cane from 6 pots of 32–8560 cane ranged from 8.3 to 10.9.

YIELD PER CENT CANE*

Duplicate pot numbers					
5	13	18	26	40	48
9.1	10.9	10.6	10.0	9.2	8.3

* Project A 105—No. 170.

Variation in Sugar Yields

To complete the picture of variations with which sugar cane investigators must deal, a few instances of the many variations in sugar yields from units of identically treated cane are offered. In Figs. 19 and 20 these are taken from two of the Blank Tests; in Fig. 21 they come from one of the "strip" layouts. Finally, even the carefully controlled pot tests can show such differences between duplicated pots as these.

4	[illegible]	14	19	24	29	34	39
10.8	11.1	13.2	11.6	7.3	11.3	10.6	9.6

Fig. 19. Sugar yields, as tons per acre, from middle sections of 500' cane rows in adjacent 10-row plots of Waialua Blank Test.

43	44	45	46 *	47	48	49	50	51 *	52
7.3	10.0	[illegible].3	7.9	9.7	10.5	9.7	10.4	10.1	8.8

Fig. 20. T.S.A. from block of plots in Hilo Field 19 Blank Test. (* These plots produced identical T.C.A. 81 tons.)

3	7 *	11 *	15	19
6.3	8.4	6.7	7.2	5.4

Fig. 21. T.S.A. from sections of 10-line strip of 31-2806 cane in Grove Farm Expt. 95 V. (* Plots Nos. 7 and 11 had identical cane yields - 65 tons per acre.)

C 104	B [illegible]			B 88	C 76	C 59	B 60	
	B 89	C 90	C 80	B 93			B 7[illegible]	C 83
C 99	B 89			B 116	C 99	C 94	B 90	

Fig. 22. T.C.A. from replicated plots in Hutchinson Expt. 50.
B plots: Range 60 - 116; average 87.
C plots: Range 59 - 104; average 87.

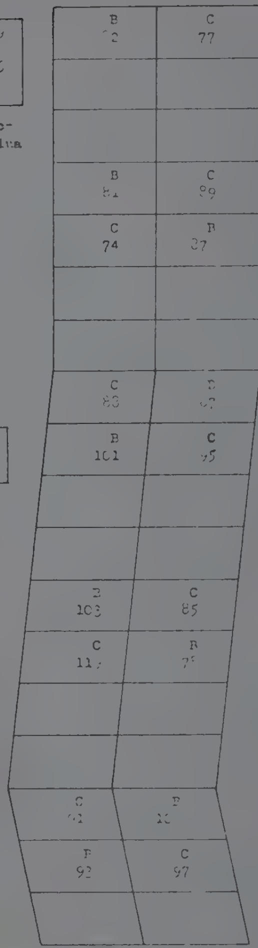

Fig. 23. T.C.A. from replicated plots in Kekaha Expt. 17.
B plots: Range 78 - 103; Average 91
C plots: Range 74 - 11[illegible] Average [illegible]

SMALL POTS: POUNDS OF RECOVERABLE SUGAR*

Duplicate pot numbers					
32	33	34	35	36	37
.71	.92	.83	.82	.57	.54

* Project A 105—No. 122.1.

LARGE POTS: POUNDS OF RECOVERABLE SUGAR*

Duplicate pot numbers								
5	9	13	16	20	24	102	106	110
7.9	7.9	9.5	8.1	9.9	8.8	6.1	6.7	8.5

* Project A 105—No. 123.

The Safeguard: Replications

If the foregoing discourse upon variations in many of our sugar cane measurements has seemed an unduly long prologue, it is nevertheless an attempt to present critical facts as we have found them. And although such a presentation may seem to have put us up against a rather hopeless and confusing set of actualities, we know that there are certain safeguards which, if adequately and correctly used, will enable us to make sense out of these measurement variations.

The most valuable of these safeguards is repetition or what we more commonly call replication, for this will quite largely distribute these normal variations impartially, and also in such a way that their effects can be identified and measured, if desired. The following examples which are taken from Grade A field experiments will illustrate how a wide range in cane yields harvested from replicated plots which have received identical treatments can "average out" to about the same value when the existing variations are given an unbiased opportunity for impartial distribution to the different treatments. Thus although a series of 9 "B" plots in Hutchinson Experiment 50 produced a wide range of between 60 and 116 tons cane per acre, and their adjacent "C" plots varied between 59 and 104 tons, yet in both series with these wide yield variations the average yield of these 9 plots was the same, i.e., 87 tons per acre (Fig. 22). Similarly from Kekaha Experiment 17 we note that identical average yields of cane were harvested from 9 replicated plots of both Treatment B and Treatment C even though the range in cane yields within each group of 9 plots was extensive (Fig. 23). Many similar instances are on record which show this "evening-up" tendency for normal variations which replication provides. This applies to yield per cent cane values as well as to cane yields. Thus two series of 8 plots each in Ewa Experiment 368K showed a range in Y%C from 11.4 to 13.5 and between 11.2 and 13.7 respectively, yet averaged out to 12.6 and 12.5. And the cane in each of two series of 9 plots from Kaiwiki Experiment 77 averaged 8.5 in Y%C from the 9 separate values which ranged from 6.6 to 9.9 in one series and between 6.8 and 10.1 in the other.

Probably no scientific worker ever actually had too much information or too many measurements from the standpoint of establishing reliable conclusions. No one will argue that a measurement or value from a single sample furnishes as reliable an estimate of the whole as the average value obtained from many samples, *when a proper sampling technique is used*, yet economy of time and labor too frequently limits the number of samples which the investigator is allowed to take. Thereafter, even though his measurements are carefully made with precision instruments and his minutely executed analysis gives him great personal satisfaction, such precision cannot safely be the critique upon which the reliability of his findings is based.

Without an adequacy of samples the accuracy of all hypotheses made therefrom

must suffer. This can be illustrated by an example from Pepeekeo Experiment 50. In Fig. 24 we show the cane yields and relative positions of 10 blocks of plots, each block carrying one plot of each of 3 different treatments, which we have identified simply as X, B, and C, in order to keep this discussion purely objective.

Let us look first at Block No. 1. Here the cane yields from the 3 treatments were identical, and if this had been the full extent of our comparisons we would be

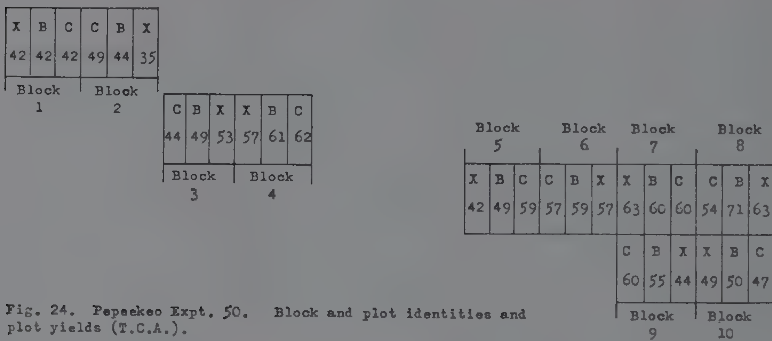

Fig. 24. Pepeekeo Expt. 50. Block and plot identities and plot yields (T.C.A.).

forced to interpret these 42-ton yields as showing no difference in the effect from the 3 treatments. On the other hand if our comparisons had been made only from Block No. 2 our conclusion would have been a very different one, for it would certainly appear that "C" had produced more cane than "B" and that "B" had produced more than "X" in this block. In fact a 14-ton difference between "C" and "X" would have been an easily visible difference and could have been noted from observation alone, both before and at harvest. Thus this example has its word of warning for those who would depend upon single "observation tests," for one would certainly be misled by the information obtained from either one of these blocks alone.

And wait! Look at the yields in Block No. 3 where we now find just the reverse of what we had in Block No. 2, for here the "X" plot has produced more cane than the "B" plot and "B" has produced more than "C." This 9-ton difference between "X" and "C," which here favors "X," was sufficiently large to have been noted by observation, too. Hence, if our comparison, either by observation or by actual yield measurement, had been made only in Block No. 3, our interpretation of treatment effect would have been a still different one.

A further inspection of the comparative yields in the other blocks reveals many further discrepancies. Thus in Blocks No. 4, 6, 7, and 10 the differences between the 3 treatment effects are not very large and they do not consistently favor any one treatment. In Blocks No. 5 and 9 the yields from "C" were greater than from "B" or "X," and "B" was ahead of "X" whereas in Block No. 8 we note "B" better than X or C but here "X" is higher than "C." Confusing? Perhaps so, but problems of a biological source have never been easy to solve, and effects from known differential treatments are not always easy to identify positively because natural variations are so common and extensive and not so easily recognized.

Conclusion

We are forced to the conclusion that, in order to allow for the unbiased distribution of natural variation which we have shown to exist in all basic materials which are measured and analyzed by the sugar cane research worker, the most effective way to obtain greater accuracy is to increase the number of replications of samples. We believe that it is far better to have measurements or analyses made from many samples by means of rapid approximate methods than to spend an equivalent time making ultra-refined measurements on only a few samples, because the extent of the variations involved in the sample itself is likely to be much greater than in the measurement concerned, if trained workers are involved in the investigation. But due to a limited labor supply, replication tends to offer us difficulty and the natural tendency is to take fewer but perhaps larger samples or perhaps to composite many carefully obtained samples and thereby reduce the required analytical work. Increasing the unit sample size may help somewhat to increase accuracy but not to the same extent as increasing the replicates, and for comparative purposes much valuable information is lost when separate samples are composited. Therefore, to the careful investigator, replication becomes his fundamental tool, by means of which he obtains a measure of the reliability of his results at the same time that he gets his desired measurements. Thus if he had only one "X" sample and one "Y" sample he could have only one difference and this difference would be a measure of both the treatment effect and the uncontrolled effects. If, however, he had provided several replicates of his X and Y treatment, and designed his investigation to give an effective control of the uncontrolled variations, he can then estimate the amount of influence from these uncontrolled effects and thereafter make a less biased comparison of the actual treatment effects—which is what he actually wants to do.

The Synthesis of Sucrose in the Sugar Cane Plant—II

The effects of several inorganic and organic compounds upon the interconversion of glucose and fructose and the formation of sucrose in detached organs of the sugar cane plant

By Constance E. Hartt

1. Inorganic Nutrients and the Formation of Sucrose

Phosphorus:

Six tests have been conducted in which blades were supplied with phosphate along with 5 per cent glucose. In five of these tests the blades with phosphate had better synthetic efficiencies than the blades without phosphate, but in one test the blades with phosphate had a lower synthetic efficiency than the blades without phosphate. The results of one of these tests are presented in full in Tables I and II, and the results of the other tests are summarized in Table III.

TABLE I

MOISTURE AND SUGAR PERCENTAGES IN BLADES SUPPLIED WITH 5% GLUCOSE AND DIFFERENT AMOUNTS OF NaH_2PO_4 FOR 24 HOURS

Grams NaH_2PO_4 per liter	Moisture	Reducing sugars	Sucrose	Total sugars
Initial control	73.02 ± 0.033	1.066 ± 0.009	2.281 ± 0.000	3.468 ± 0.008
0	72.37 ± 0.024	1.565 ± 0.000	4.598 ± 0.022	6.406 ± 0.024
0.4	72.20 ± 0.076	1.478 ± 0.002	4.478 ± 0.003	6.191 ± 0.000
2.1	72.24 ± 0.157	1.558 ± 0.031	4.959 ± 0.133	6.779 ± 0.109
8.3	71.49 ± 0.076	1.687 ± 0.002	5.371 ± 0.035	7.341 ± 0.034

TABLE II

GAINS IN SUGARS AND SYNTHETIC EFFICIENCIES OF BLADES SUPPLIED WITH 5% GLUCOSE AND DIFFERENT AMOUNTS OF NaH_2PO_4 FOR 24 HOURS, CALCULATED FROM TABLE I

Grams NaH_2PO_4 per liter	Gain in total sugars	Gain in sucrose	Synthetic efficiency
0	2.938	2.317	78.86
0.4	2.723	2.197	80.68
2.1	3.311	2.678	80.88
8.3	3.873	3.090	79.78

Plants were grown in aerated nutrient solutions with and without phosphate. At a little less than two months of age, when the tops of the plants supplied with phosphate were twice as tall as those of the plants deprived of phosphate, the plants were

TABLE III

GAINS IN SUGARS AND SYNTHETIC EFFICIENCIES OF BLADES SUPPLIED WITH 5% GLUCOSE OR FRUCTOSE AND 0.8% NaH_2PO_4 OR KH_2PO_4 FOR 24 HOURS

Phosphate supplied	Sugar supplied	Gain in total sugars	Gain in sucrose	Synthetic efficiency
0	Glucose	3.227	2.439	75.58
0	Fructose	2.922	1.930	66.05
0	Both	2.801	2.065	73.72
NaH_2PO_4	Glucose	3.463	3.343	96.53
NaH_2PO_4	Fructose	3.311	3.103	93.71
NaH_2PO_4	Both	3.167	3.169	100.06
0	Glucose	3.198	2.469	77.20
NaH_2PO_4	Glucose	3.364	2.783	82.73
0	Glucose	2.482	1.835	73.93
NaH_2PO_4	Glucose	2.756	1.851	67.16
0	Glucose	2.888	2.152	74.51
NaH_2PO_4	Glucose	3.111	2.438	78.36
KH_2PO_4	Glucose	2.189	1.766	80.67
0	Glucose	4.341	3.487	80.32
KH_2PO_4	Glucose	4.034	3.346	82.94

removed from their solutions, the roots were cut from the tops, and were washed and centrifuged as usual. The excised roots and the entire tops were supplied with 5 per cent glucose for 24 hours. The moisture and sugar percentages are presented in Table IV, the gains in sugars and the synthetic efficiencies in Table V, and the fructose and glucose percentages in Table VI. The roots of the plants grown with

TABLE IV

MOISTURE AND SUGAR PERCENTAGES IN EXCISED ROOTS AND ENTIRE TOPS OF PLANTS GROWN WITH AND WITHOUT PHOSPHATE AND SUPPLIED WITH 5% GLUCOSE FOR 24 HOURS

Series	Moisture	Reducing sugars	Sucrose	Total sugars
Initial control:				
Roots + P	**88.38** ± 0.219	**1.670** ± 0.014	**1.641** ± 0.003	**3.397** ± 0.017
Roots − P	**87.07** ± 0.005	**2.200** ± 0.000	**1.286** ± 0.035	**3.554** ± 0.036
Tops + P	**83.29** ± 0.133	**4.421** ± 0.001	**3.675** ± 0.023	**8.289** ± 0.025
Tops − P	**81.16** ± 0.062	**2.535** ± 0.063	**4.088** ± 0.078	**6.839** ± 0.146
In glucose:				
Roots + P	**88.48** ± 0.048	**7.961** ± 0.028	**6.069** ± 0.068	**14.350** ± 0.044
Roots − P	**87.30** ± 0.009	**9.457** ± 0.033	**6.351** ± 0.039	**16.143** ± 0.008
Tops + P	**80.76** ± 0.014	**5.441** ± 0.007	**4.797** ± 0.032	**10.491** ± 0.040
Tops − P	**78.16** ± 0.215	**4.328** ± 0.032	**5.496** ± 0.016	**10.114** ± 0.016

TABLE V

GAINS IN SUGARS AND SYNTHETIC EFFICIENCIES IN EXCISED ROOTS AND ENTIRE TOPS OF PLANTS GROWN WITH AND WITHOUT PHOSPHATE AND SUPPLIED WITH 5% GLUCOSE FOR 24 HOURS, CALCULATED FROM TABLE IV

Series	Gain in total sugars	Gain in sucrose	Synthetic efficiency
Roots + P	10.953	4.428	40.42
Roots — P	12.589	5.065	40.23
Tops + P	2.202	1.122	50.95
Tops — P	3.275	1.408	42.99

TABLE VI

FRUCTOSE AND GLUCOSE PERCENTAGES IN EXCISED ROOTS AND ENTIRE TOPS OF PLANTS GROWN WITH AND WITHOUT PHOSPHATE AND SUPPLIED WITH 5% GLUCOSE FOR 24 HOURS

Series	Fructose	Gain in fructose	Glucose	Gain in glucose
Initial control:				
Roots + P	0		**1.670** ± 0.014	
Roots — P	**1.097** ± 0.005		**1.103** ± 0.005	
Tops + P	**2.694** ± 0.011		**1.726** ± 0.009	
Tops — P	**2.289** ± 0.013		**0.245** ± 0.077	
In glucose:				
Roots + P	**2.044** ± 0.048	2.044	**5.917** ± 0.075	4.247
Roots — P	**1.754** ± 0.010	0.657	**7.703** ± 0.023	6.600
Tops + P	**3.251** ± 0.142	0.557	**2.190** ± 0.135	0.464
Tops — P	**2.545** ± 0.007	0.256	**1.783** ± 0.040	1.538

and without phosphate did not differ in synthetic efficiency. But the tops of the plants grown with phosphate had a higher synthetic efficiency than the tops of the plants grown without phosphate. Both the roots and the tops made greater gains in fructose in the plants grown with phosphate, and greater gains in glucose in the plants grown without phosphate. These results suggest that phosphate is important in the conversion of glucose to fructose as well as in the synthesis of sucrose.

In another experiment, in which plants were grown with and without phosphate for three months, detached roots were supplied with glucose in aerated culture for 24 hours, with two replications per series. The synthetic efficiency of the roots grown with phosphate was 34.31 ± 2.499, while that of the roots grown without phosphate was only 2.92 ± 1.025.

An experiment was then conducted to determine whether plants grown with and without phosphate for three months would have the synthetic efficiencies of their blades and roots equalized by the addition of phosphate along with the glucose in the synthesis test. For this purpose sodium phosphate and adenylic acid were used. Adenylic acid was chosen because it is an organic phosphate compound and because

studies with other organisms have shown the importance of adenosine triphosphate in the transfer of organic phosphate to glucose. Adenylic acid (= adenosine monophosphate) was obtainable whereas adenosine triphosphate was not. The results of the determinations of moisture and sugars are presented in Table VII, the gains in sugars and the synthetic efficiencies in Table VIII, and the percentages of glucose and fructose in Table IX.

TABLE VII

MOISTURE AND SUGAR PERCENTAGES IN EXCISED ROOTS AND BLADES OF PLANTS GROWN WITH AND WITHOUT PHOSPHATE FOR 3 MONTHS AND SUPPLIED WITH 5% GLUCOSE WITH AND WITHOUT NaH_2PO_4 AND ADENYLIC ACID FOR 24 HOURS

Series	Moisture	Reducing sugars	Sucrose	Total sugars
Roots:				
Initial control + P ...	87.31 ± 0.014	1.500 ± 0.002	2.161 ± 0.009	3.776 ± 0.012
Initial control — P ...	85.39 ± 0.033	0.178 ± 0.009	1.125 ± 0.007	1.363 ± 0.003
Glucose + P	87.52 ± 0.105	10.345 ± 0.011	7.737 ± 0.005	18.490 ± 0.017
Glucose + P	88.27 ± 0.272	10.279 ± 0.050	6.758 ± 0.017	17.394 ± 0.068
Glucose — P	87.03	10.323 ± 0.017	2.241 ± 0.008	12.682 ± 0.009
Glucose — P	86.53 ± 0.062	9.949 ± 0.015	1.998 ± 0.005	12.052 ± 0.020
Glucose + NaH_2PO_4 + P	86.78 ± 0.172	8.732 ± 0.005	6.707 ± 0.059	15.793 ± 0.067
Glucose + NaH_2PO_4 — P	87.57 ± 0.009	10.879 ± 0.008	0.926 ± 0.049	11.854 ± 0.059
Blades:				
Initial control + P ...	73.64 ± 0.043	2.381 ± 0.009	2.341 ± 0.016	4.895 ± 0.050
Initial control — P ...	69.15 ± 0.148	0.566 ±0.015	2.335 ± 0.004	3.024 ± 0.011
Glucose + P	69.44 ± 0.043	6.215 ± 0.047	12.806 ± 0.004	19.695 ± 0.042
Glucose — P	65.26 ± 0.038	3.891 ± 0.037	7.022 ± 0.029	11.283 ± 0.007
Glucose + NaH_2PO_4 + P	70.48 ± 0.133	5.781 ± 0.063	12.089 ± 0.066	18.507 ± 0.133
Glucose + NaH_2PO_4 — P	64.60 ± 0.000	3.919	7.677	12.000
Glucose + adenylic acid + P	69.04 ± 0.129	6.417 ± 0.029	13.438 ± 0.042	20.562 ± 0.015
Glucose + adenylic acid — P	64.53 ± 0.272	4.223 ± 0.014	7.711 ± 0.020	12.340 ± 0.008
Glucose + NaH_2PO_4 + adenylic acid + P ..	69.54 ± 0.081	6.248	12.263	19.157
Glucose + NaH_2PO_4 + adenylic acid — P ..	64.32 ± 0.277	4.056 ± 0.050	7.765 ± 0.056	12.230 ± 0.009

Tables VII and VIII show that the blades and roots of the plants grown with phosphate contained higher percentages of reducing sugars and sucrose than did those of the plants grown without phosphate. The blades and roots of the plants supplied with phosphate also made greater gains in total sugars and sucrose and had higher synthetic efficiencies than did those of the plants deprived of phosphate. Greater gains in glucose and smaller gains in fructose were obtained in the blades and roots of the plants grown without phosphate than in those of the plants grown with phosphate. These findings prove that phosphate plays an important rôle in the conversion of glucose to fructose and the synthesis of sucrose.

TABLE VIII

GAINS IN SUGARS AND SYNTHETIC EFFICIENCIES IN EXCISED ROOTS AND BLADES OF PLANTS GROWN WITH AND WITHOUT PHOSPHATE FOR THREE MONTHS AND SUPPLIED WITH 5% GLUCOSE WITH AND WITHOUT NaH_2PO_4 AND ADENYLIC ACID FOR 24 HOURS, CALCULATED FROM TABLE VII

Series	Gain in total sugars	Gain in sucrose	Synthetic efficiency	
Roots:				
Glucose + P	14.714	5.576	37.89	35.82 ± 0.987
Glucose + P	13.618	4.597	33.75	
Glucose — P	11.319	1.116	9.85	9.00 ± 0.401
Glucose — P	10.689	0.873	8.16	
Glucose + NaH_2PO_4 + P	12.017	4.546	37.82	
Glucose + NaH_2PO_4 — P	10.491	–0.199	0	
Blades:				
Glucose + P	14.800	10.465	70.70	
Glucose — P	8.259	4.687	56.75	
Glucose + NaH_2PO_4 + P	13.612	9.748	71.61	
Glucose + NaH_2PO_4 — P	9.976	5.342	53.54	
Glucose + adenylic acid + P	15.667	11.097	70.83	
Glucose + adenylic acid — P	9.316	5.376	57.70	
Glucose + adenylic acid + NaH_2PO_4 + P	14.262	9.922	69.56	
Glucose + adenylic acid + NaH_2PO_4 — P	9.206	5.430	58.98	

TABLE IX

FRUCTOSE AND GLUCOSE PERCENTAGES IN EXCISED ROOTS AND BLADES OF PLANTS GROWN WITH AND WITHOUT PHOSPHATE FOR THREE MONTHS AND SUPPLIED WITH 5% GLUCOSE WITH AND WITHOUT NaH_2PO_4 AND ADENYLIC ACID FOR 24 HOURS

Series	Fructose	Gain in fructose		Glucose	Gain in glucose	
Roots:						
Initial control + P	0			1.500 ± 0.002		
Initial control — P	0			0.178 ± 0.009		
Glucose + P	1.076 ± 0.018	1.076	1.208 ± 0.063	9.269 ± 0.029	7.769	7.604 ± 0.079
Glucose + P	1.340 ± 0.036	1.340		8.939 ± 0.086	7.439	
Glucose — P	0.803 ± 0.046	0.803	0.697 ± 0.050	9.520 ± 0.029	9.342	9.260 ± 0.039
Glucose — P	0.592 ± 0.014	0.592		9.357 ± 0.029	9.179	
Glucose + NaH_2PO_4 + P	1.041 ± 0.017	1.041		7.691 ± 0.022	6.191	
Glucose + NaH_2PO_4 — P	0	0		10.879 ± 0.008	10.701	
Blades:						
Initial control + P	0.500 ± 0.025			1.880 ± 0.034		
Initial control — P	0			0.566 ± 0.015		
Glucose + P	1 672 ± 0.015	1.172		4.543 ± 0.062	2.663	
Glucose — P	0.651 ± 0.048	0.651		3.240 ± 0.010	2.674	
Glucose + NaH_2PO_4 + P	1.524 ± 0.013	1.024		4.257 ± 0.050	2.377	
Glucose + NaH_2PO_4 — P	0.521 ± 0.047	0.521		3.496	2.930	
Glucose + adenylic acid + P	1.581 ± 0.019	1.081		4.835 ± 0.009	2.955	
Glucose + adenylic acid — P	0	0		4.223 ± 0.014	3.657	
Glucose + adenylic acid + NaH_2PO_4 + P	1.879	1.379		4.369	2.489	
Glucose + adenylic acid + NaH_2PO_4 — P	0.629 ± 0.060	0.629		3.426 ± 0.009	2.860	

Supplying sodium phosphate to the excised blades and roots of the plants grown without phosphate did not increase their synthetic efficiencies, according to Table VIII. Evidently the mere presence of inorganic phosphate is not enough to insure a good ability to make sucrose from glucose. Since phosphate is important in inter-

conversion and synthesis, but inorganic phosphate is not able to make up the deficiency in synthesis tests using plants grown without phosphate, we may conclude that organic phosphate is required for interconversion and synthesis. This conclusion is in accord with the results obtained in an experiment with the enzyme phosphatase, to be presented in another section.

Supplying organic phosphate in the form of adenylic acid to the blades of the plants grown without phosphate resulted in only minor increases in synthetic efficiency, as shown in Table VIII. It is evident that the exact form of organic phosphate required has not yet been found. This subject is treated from a different angle in the third part of this study, dealing with the effects of specific inhibitors upon enzyme action.

Although inorganic phosphate did not increase the synthetic efficiency of the blades of the plants grown without phosphate, there was a small gain in the blades of the plants grown with phosphate, according to Table VIII. This result thus agrees with those already recorded in Tables I-III. Perhaps the addition of inorganic phosphate to the blades of plants grown with phosphate checks the conversion of organic phosphate to inorganic phosphate and thus favors synthesis. This idea is in agreement with the results of the phosphatase tests to be presented in another section. Phosphatase, an enzyme which converts organic phosphate to inorganic, decreases the synthesis of sucrose.

These experiments show that phosphorus is a very important element in the conversion of glucose to fructose and the synthesis of sucrose. It is probable that the form of phosphate required is organic.

Nitrogen:

Blades were taken from plants grown in the field with 0, 100, and 200 pounds nitrogen per acre, and were supplied with 5 per cent glucose for 24 hours. The results for moisture and sugars are reported in Table X, and the gains in sugars and synthetic efficiencies in Table XI. Both the gain in total sugars and the gain in sucrose were negatively correlated with the amount of nitrogen supplied, indicating either that nitrogen interfered with the absorption of sugar, or that some of the sugar absorbed by the blades of the high-nitrogen series reacted with nitrogenous compounds. The synthetic efficiency was best in the blades of the plants grown with 200 pounds N per acre. The activity of invertase was determined in these blades and the results are presented in Table XII. The results are expressed in cc. N/20 $KMnO_4$ and represent the increase in reducing action using 3 per cent

TABLE X

MOISTURE AND SUGAR PERCENTAGES IN BLADES OF PLANTS GROWN WITH DIFFERENT AMOUNTS OF NITROGEN AND SUPPLIED WITH 5% GLUCOSE FOR 24 HOURS

Series	Moisture	Reducing sugars	Sucrose	Total sugars
Initial control:				
0 N	74.51	1.037 ± 0.012	1.738 ± 0.015	2.866 ± 0.003
100 lbs. N	73.03 ± 0.038	0.968 ± 0.009	1.788 ± 0.014	2.851 ± 0.005
200 lbs. N	74.63 ± 0.043	1.070 ± 0.013	1.739 ± 0.013	2.902 ± 0.000
In glucose:				
0 N	72.98 ± 0.129	1.298 ± 0.002	3.833 ± 0.023	5.333 ± 0.022
100 lbs. N	71.47 ± 0.362	1.172 ± 0.008	3.378 ± 0.043	4.728 ± 0.038
200 lbs. N	72.96 ± 0.095	1.077 ± 0.022	3.045 ± 0.010	4.283 ± 0.010

TABLE XI

GAINS IN SUGARS AND SYNTHETIC EFFICIENCY OF BLADES OF PLANTS GROWN WITH DIFFERENT AMOUNTS OF NITROGEN AND SUPPLIED WITH 5% GLUCOSE FOR 24 HOURS, CALCULATED FROM TABLE X

Series	Gain in total sugars	Gain in sucrose	Synthetic efficiency
0 N	2.467	2.095	84.92
100 lbs. N	1.877	1.590	84.70
200 lbs. N	1.381	1.306	94.56

TABLE XII

INVERTASE ACTIVITY IN BLADES OF PLANTS GROWN WITH DIFFERENT AMOUNTS OF NITROGEN AND SUPPLIED WITH 5% GLUCOSE FOR 24 HOURS, EXPRESSED IN CC. N/20 $KMnO_4$

Amount of N	Invertase	
	Initial controls	In glucose
0	15.03	18.38
100 lbs.	17.79	17.24
200 lbs.	18.96	16.57

sucrose at pH 4.5 as the medium. The activity of invertase in the initial controls was positively correlated with the amount of nitrogen, but in the blades supplied with glucose for 24 hours, the activity of invertase was inversely correlated with the amount of nitrogen. In another experiment plants were grown in sand cultures with different amounts of nitrogen and the activity of invertase was determined in separate organs, at pH 4.5, with the results reported in Table XIII. The activity of invertase was positively correlated with the amount of nitrogen in all organs.

TABLE XIII

INVERTASE ACTIVITY IN PLANTS GROWN WITH DIFFERENT AMOUNTS OF NITROGEN, EXPRESSED IN CC. N/20 $KMnO_4$

Series	Blades	Sheaths	Grean-leaf cane	Dry-leaf cane
Complete	17.41	25.87	31.02	50.75
Low N	8.08	13.38	21.29	10.29
No N	7.83	12.71		7.86

Summing up the results with plants grown with different amounts of nitrogen, it appears that both the synthetic efficiency and the activity of invertase were greatest in the plants grown with high nitrogen.

To find the effect of supplying blades with different amounts of nitrogen along with the glucose, experiments were conducted using sodium nitrate and ammonium sulphate. The results of the experiment with sodium nitrate are recorded in Tables XIV to XVI. The synthetic efficiency was increased by the addition of 100-200 p.p.m. N as sodium nitrate, but greatly decreased by the addition of 400-800 p.p.m. N. The conversion of glucose to fructose was also decreased by 400-800 p.p.m. N.

TABLE XIV

MOISTURE AND SUGAR PERCENTAGES IN BLADES SUPPLIED WITH DIFFERENT AMOUNTS OF $NaNO_3$ IN 5% GLUCOSE FOR 24 HOURS

p.p.m. N	Moisture	Reducing sugars	Sucrose	Total sugars
Initial control	70.96 ± 0.124	0.949 ± 0.035	2.737 ± 0.012	3.832 ± 0.023
0	70.32 ± 0.143	2.718 ± 0.000	7.630 ± 0.014	10.750 ± 0.014
100	68.44 ± 0.148	2.157 ± 0.002	6.768 ± 0.010	9.281 ± 0.009
200	69.58 ± 0.052	2.231 ± 0.002	7.128 ± 0.017	9.734 ± 0.015
400	68.55 ± 0.076	2.557 ± 0.025	5.080 ± 0.002	7.904 ± 0.028
800	68.58 ± 0.153	4.790 ± 0.008	3.875 ± 0.007	8.870 ± 0.015

The results of the experiment with ammonium sulphate are reported in Tables XVII-XIX. Contrary to the findings with sodium nitrate, ammonium sulphate appeared to have no definite effect upon the synthetic efficiency or upon the conversion of glucose to fructose. Since sodium nitrate (400-800 p.p.m. N) decreased the synthetic efficiency, whereas ammonium sulphate (also 400-800 p.p.m. N) had no effect upon the synthetic efficiency, one may conclude either that the deleterious factor in sodium nitrate is the sodium or that the effects of nitrate and ammonium upon synthesis are different. Table II shows that sodium phosphate had no deleterious effect upon synthesis, for which reason it is concluded that sodium is not the inhibitory factor. Therefore these tests indicate that supplying high amounts of nitrate directly to the blades decreased their synthetic efficiency. No tests were made of the actual nitrate content of the blades, but since the detached blades were placed directly in the solutions of nitrate it is possible that the blades contained some nitrate. Normal attached blades, however, growing in the field and supplied with nitrate fertilizer have never been found to contain nitrate, due to the rapid reduction of nitrate which is known to take place in the roots.

TABLE XV

GAINS IN SUGARS AND SYNTHETIC EFFICIENCY OF BLADES SUPPLIED WITH DIFFERENT AMOUNTS OF $NaNO_3$ IN 5% GLUCOSE FOR 24 HOURS, CALCULATED FROM TABLE XIV

p.p.m. N	Gain in total sugars	Gain in sucrose	Synthetic efficiency
0	6.918	4.893	70.72
100	5.449	4.031	73.97
200	5.902	4.391	74.39
400	4.072	2.343	57.53
800	5.038	1.138	22.58

TABLE XVI

FRUCTOSE AND GLUCOSE PERCENTAGES IN BLADES SUPPLIED WITH DIFFERENT AMOUNTS OF $NaNO_3$ IN 5% GLUCOSE FOR 24 HOURS

p.p.m. N	Fructose	Gain in fructose	Glucose	Gain in glucose
Initial control	0.562 ± 0.032		0.387 ± 0.003	
0	1.381 ± 0.155	0.819	1.336 ± 0.155	0.949
100	1.067 ± 0.074	0.505	1.089 ± 0.076	0.702
200	1.053 ± 0.012	0.491	1.178 ± 0.009	0.791
400	0.587 ± 0.006	0.015	1.969 ± 0.019	1.582
800	0.816 ± 0.012	0.254	3.974 ± 0.005	3.587

TABLE XVII

MOISTURE AND SUGAR PERCENTAGES IN BLADES SUPPLIED WITH DIFFERENT AMOUNTS OF $(NH_4)_2SO_4$ IN 5% GLUCOSE FOR 24 HOURS

p.p.m. N	Moisture	Reducing sugars	Sucrose	Total sugars
Initial control	**67.99** ± 0.071	**0.945** ± 0.028	**3.161** ± 0.011	**4.273** ± 0.016
0	**67.09** ± 0.167	**1.548** ± 0.033	**6.699** ± 0.018	**8.601** ± 0.014
100	**66.84** ± 0.205	**1.293** ± 0.016	**5.802** ± 0.037	**7.400** ± 0.055
200	**66.62** ± 0.014	**1.685** ± 0.033	**6.367** ± 0.012	**8.388** ± 0.046
400	**66.31** ± 0.009	**1.328** ± 0.002	**5.702** ± 0.019	**7.330** ± 0.022
800	**66.44** ± 0.038	**1.493** ± 0.023	**5.350** ± 0.005	**7.125** ± 0.028

TABLE XVIII

GAINS IN SUGARS AND SYNTHETIC EFFICIENCY OF BLADES SUPPLIED WITH DIFFERENT AMOUNTS OF $(NH_4)_2SO_4$ IN 5% GLUCOSE FOR 24 HOURS, CALCULATED FROM TABLE XVII

p.p.m. N	Gain in total sugars	Gain in sucrose	Synthetic efficiency
0	4.328	3.538	81.75
100	3.127	2.641	84.46
200	4.115	3.206	77.91
400	3.057	2.541	83.12
800	2.852	2.189	76.75

TABLE XIX

FRUCTOSE AND GLUCOSE PERCENTAGES IN BLADES SUPPLIED WITH DIFFERENT AMOUNTS OF $(NH_4)_2SO_4$ IN 5% GLUCOSE FOR 24 HOURS

p.p.m. N	Fructose	Gain in fructose	Glucose	Gain in glucose
Initial control	**0.488** ± 0.024		**0.457** ± 0.004	
0	**0.939** ± 0.025	0.451	**0.609** ± 0.058	0.152
100	**1.067** ± 0.016	0.579	**0.226** ± 0.000	−0.231
200	**0.956** ± 0.020	0.468	**0.729** ± 0.013	0.272
400	**0.400** ± 0.003	−0.088	**0.927** ± 0.000	0.470
800	**0.718** ± 0.004	0.230	**0.774** ± 0.019	0.317

These experiments with nitrogen indicate that growing plants with a deficient supply of nitrogen decreases both the activity of invertase and the synthetic efficiency, but that supplying a surplus of nitrate to the blades interferes both with the conversion of glucose to fructose and with the synthesis of sucrose.

2. Organic Compounds and the Formation of Sucrose

Invertase:

Studies of potassium deficiency in sugar cane reported in 1934 (31)* were thought to offer indirect evidence that sucrose in the sugar cane plant is synthesized by invertase. Oparin (66) claimed to have synthesized sucrose by the simultaneous action of invertase and phosphatase of yeast. Using the method of vacuum infiltration, Kurssanov (48) found that the introduction of very weak concentrations of invertase into leaves stimulated the formation of sucrose from glucose. Studies of the effect of invertase, using "Convertit" prepared by Wallerstein Company were therefore undertaken.

* Numbers in parentheses refer to literature citations at the end of the fourth part of this paper.

When blades were placed in five and ten per cent solutions of Convertit, they absorbed the Convertit which resulted in almost complete inversion of the sucrose already present in the blades. An experiment was then conducted in which the weak concentrations of Convertit suggested by Kurssanov were used. The blades used in this experiment were obtained from plants deficient in nitrogen, since it had already been found that invertase activity is weak in plants deprived of nitrogen. The blades were supplied with Convertit for 24 hours, followed by 5 per cent glucose for 24 hours. The results for moisture and sugars are presented in Table XX,

TABLE XX

MOISTURE AND SUGAR PERCENTAGES IN BLADES SUPPLIED WITH CONVERTIT FOR 24 HOURS FOLLOWED BY 5% GLUCOSE FOR 24 HOURS

% Convertit	Moisture	Reducing sugars	Sucrose	Total sugars
Initial control	**68.41** ± 0.043	**0.860** ± 0.045	**2.208** ± 0.046	**3.184** ± 0.093
0	**67.12** ± 0.200	**1.206** ± 0.009	**6.246** ± 0.006	**7.782** ± 0.016
0.01	**68.57** ± 0.143	**1.554** ± 0.006	**6.431** ± 0.008	**8.324** ± 0.014
0.025	**66.98** ± 0.086	**1.294** ± 0.012	**5.840** ± 0.031	**7.442** ± 0.020
0.05	**67.56** ± 0.076	**1.469** ± 0.045	**5.969** ± 0.034	**7.752** ± 0.009
0.10	**67.21** ± 0.029	**1.551** ± 0.040	**5.105** ± 0.057	**6.925** ± 0.019
0.25	**66.53** ± 0.133	**2.230** ± 0.041	**5.200** ± 0.014	**7.703** ± 0.026

TABLE XXI

GAINS IN SUGARS AND SYNTHETIC EFFICIENCY OF BLADES SUPPLIED WITH CONVERTIT FOR 24 HOURS FOLLOWED BY 5% GLUCOSE FOR 24 HOURS, CALCULATED FROM TABLE XX

% Convertit	Gain in total sugars	Gain in sucrose	Synthetic efficiency
0	4.598	4.038	87.8
0.01	5.140	4.223	82.1
0.025	4.258	3.632	85.2
0.05	4.568	3.761	82.3
0.10	3.741	2.897	77.4
0.25	4.519	2.992	66.2

TABLE XXII

INVERTASE ACTIVITY IN BLADES SUPPLIED WITH CONVERTIT FOR 24 HOURS FOLLOWED BY 5% GLUCOSE FOR 24 HOURS, EXPRESSED IN CC. N/20 $KMnO_4$

Per cent Convertit	Invertase at pH 4.5
Initial control	10.18
0	9.22
0.01	10.73
0.025	13.00
0.05	18.11
0.10	23.04
0.25	38.06

and the gains in sugars and synthetic efficiencies are recorded in Table XXI. The activity of invertase is shown in Table XXII. The activity of invertase in the blades was positively correlated with the percentage of Convertit supplied, indicating that the blades absorbed the Convertit. But the absorption of Convertit did not aid synthesis, as the synthetic efficiencies of all the blades supplied with Convertit were lower than that of the blades with no Convertit. It is true that the blades supplied with 0.01 per cent Convertit made a small but significantly greater gain in sucrose

than the blades with no Convertit, but this was merely due to the fact that they absorbed more glucose, as shown by their greater gain in total sugars.

Only one test has shown an improvement in synthesis in blades supplied with Convertit. The synthetic efficiency of blades without Convertit was 83.0, while that of blades with 0.025 per cent Convertit was 85.4.

The results herein presented are not in accord with the view that invertase synthesizes sucrose. Of course one may argue that the Convertit used was not in the right form. However, it is apparent that one must search for other constituents of the mechanism for the synthesis of sucrose.

Phosphatase:

Phosphatase was prepared from veal marrow bones by the method of Martland and Robison (57). Bone phosphatase hydrolyzes fructose diphosphate forming glucose-, fructose-, and perhaps mannose-6-phosphate, according to MacLeod and Robison (56). Liebknecht (52) reported that bone phosphatase hydrolyzes adenyl pyrophosphate (= adenosine triphosphate) splitting off first the easily hydrolyzable phosphate and then the phosphate on the C_5 of the ribose. Our preparation of phosphatase could liberate inorganic phosphate from organic compounds as shown by a test with glycerophosphate. Blades were supplied with approximately 0.25 per cent of the phosphatase preparation for 24 hours, followed by 5 per cent glucose or fructose for 24 hours. The percentages of moisture and sugars are recorded in Table XXIII. The gains in sugars and the synthetic efficiency are shown in Table XXIV.

TABLE XXIII

MOISTURE AND SUGAR PERCENTAGES IN BLADES SUPPLIED WITH 0.25% PHOSPHATASE FOR 24 HOURS FOLLOWED BY 5% GLUCOSE OR FRUCTOSE FOR 24 HOURS

Series	Moisture	Reducing sugars	Sucrose	Total sugars
Initial control	72.68 ± 0.033	1.076 ± 0.010	2.766 ± 0.022	3.988 ± 0.033
Water followed by:				
Glucose	71.75 ± 0.029	1.833 ± 0.015	5.250 ± 0.011	7.360 ± 0.027
Fructose	71.39 ± 0.038	2.065 ± 0.019	4.741 ± 0.011	7.055 ± 0.007
Both	69.79 ± 0.019	1.801 ± 0.040	4.876 ± 0.031	6.934 ± 0.007
Phosphatase followed by:				
Glucose	67.74 ± 0.009	2.031 ± 0.012	3.267 ± 0.039	5.471 ± 0.053
Fructose	67.51 ± 0.062	1.856 ± 0.005	3.036 ± 0.014	5.052 ± 0.019
Both	69.38 ± 0.138	2.144 ± 0.019	3.071 ± 0.017	5.377 ± 0.001

TABLE XXIV

GAINS IN SUGARS AND SYNTHETIC EFFICIENCY OF BLADES SUPPLIED WITH 0.25% PHOSPHATASE FOR 24 HOURS FOLLOWED BY 5% GLUCOSE OR FRUCTOSE FOR 24 HOURS, CALCULATED FROM TABLE XXIII

Series	Gain in total sugars	Gain in sucrose	Synthetic efficiency
Water followed by:			
Glucose	3.372	2.484	73.66
Fructose	3.067	1.975	64.39
Both	2.946	2.110	71.62
Phosphatase followed by:			
Glucose	1.483	0.501	33.78
Fructose	1.064	0.270	25.37
Both	1.389	0.305	21.95

This experiment indicates that phosphatase hinders synthesis. In another experiment with blades phosphatase decreased the synthetic efficiency, using glucose, from 84.33 to 62.45. In an experiment with excised roots, phosphatase decreased the synthetic efficiency from 39.74 to zero. These results are in accord with the view that organic phosphate plays a rôle in the formation of sucrose.

Invertase and phosphatase are the only enzymes which have been introduced into blades. One experiment was conducted with detached roots supplied with 0.25 per cent zymin in 5 per cent glucose and the result was a decrease in the synthetic efficiency from 39.74 to zero. Other enzymes have been studied indirectly by the use of specific inhibitors, and these studies will be reported in the third paper of this series.

Hormones:

In experiments with entire plants including roots, the roots were found to absorb glucose or fructose and make sucrose; but in experiments with excised roots, the roots were found to absorb glucose or fructose but make little or no sucrose. The suggestion was made (34) that roots obtain from the tops some constituent essential for synthesis. Since aeration has been found to be a very important factor in both interconversion and synthesis, it may be that air is the constituent obtained by roots from the tops. However, even well-aerated roots seldom have a synthetic efficiency equal to that of tops. For this reason, studies of other substances known to be supplied by the tops to the roots were undertaken. The substances studied include hormones and vitamins. Other substances known to be active in lower plants or in animals are also being studied.

The hormones or growth substances used in these tests included beta indole acetic acid, beta indole butyric acid, indole-3-propionic acid, alpha-naphthalene acetic acid, and cinnamic acid. Without exception these substances reduced the synthetic efficiency of excised roots in aerated culture to zero. They also prevented the conversion of glucose to fructose.

Adenylic acid (0.001 per cent) was supplied with 5 per cent glucose in aerated culture to detached roots, and the result was a decrease in synthetic efficiency. Adenylic acid was also used in two tests with blades, resulting in an increase in synthetic efficiency.

Glutathione (0.005 per cent) was used in two tests with detached roots. In one test there was no effect upon the synthetic efficiency, and in the other test there was an increase, but probably insignificant.

Inositol (0.005 per cent) was used in two preliminary tests with detached roots, in both of which there was an increase in synthetic efficiency. However, when a test was conducted with two replications per series, there was no significant difference.

Epinephrine (0.006 per cent), used in one test with detached roots, resulted in a decrease in conversion of glucose to fructose and a decrease in synthetic efficiency. In blades, epinephrine had no effect upon the synthetic efficiency, using glucose (2 tests); in one test, in which fructose was used, epinephrine raised the synthetic efficiency from 81.19 to 88.61.

Beta alanine (0.005 per cent) was supplied to detached roots in 5 per cent glucose in one test only, and the result was a decrease in synthetic efficiency.

Insulin (0.005 per cent) was supplied to detached roots in 5 per cent glucose in one test only, and the result was a decrease in synthetic efficiency.

Glutamic acid (0.01 per cent) was supplied to detached roots in 5 per cent glucose in two tests, and the result was an increase in synthetic efficiency. There were no significant differences in a test with two replications per series.

Perhaps it should not be surprising that no hormones or growth-promoting substances have been found to increase synthesis consistently. Substances which promote growth would be more apt to stimulate hydrolysis of sucrose and its utilization in respiration and the formation of tissues, than to promote the synthesis of a storage product.

Vitamins:

The following vitamins have been used in tests with detached roots: thiamin chloride, riboflavin, nicotinic amide, pyridoxin, ascorbic acid, 2-methyl-3-phytyl-1, 4-naphthoquinone, the diphosphoric acid ester of dihydro K_1, phthiocol, and folic acid.

Thiamin chloride (0.001 per cent), also known as vitamin B_1, has been used in several tests with detached roots. A preliminary test with a single series indicated that thiamin chloride may aid synthesis. Because of the individual variation in the

TABLE XXV

MOISTURE AND SUGAR PERCENTAGES IN DETACHED ROOTS IN AERATED CULTURE WITH AND WITHOUT THIAMIN CHLORIDE IN 5% GLUCOSE

Series	Moisture	Reducing sugars	Sucrose	Total sugars
Initial control	**88.82** ± 0.038	**2.425** ± 0.007	**1.027** ± 0.012	**3.506** ± 0.005
Initial control	**88.88** ± 0.052	**2.516** ± 0.001	**0.827** ± 0.001	**3.387** ± 0.003
Glucose	**89.10** ± 0.033	**9.388** ± 0.018	**4.259** ± 0.019	**13.871** ± 0.038
Glucose	**88.72** ± 0.100	**9.150** ± 0.020	**6.181** ± 0.012	**15.656** ± 0.007
Glucose + B_1	**88.40** ± 0.114	**9.034** ± 0.007	**8.241** ± 0.120	**17.709** ± 0.119
Glucose + B_1	**88.39** ± 0.210	**8.662** ± 0.019	**7.488** ± 0.037	**16.544** ± 0.058

TABLE XXVI

GAINS IN SUGARS AND SYNTHETIC EFFICIENCY OF DETACHED ROOTS IN AERATED CULTURE WITH AND WITHOUT THIAMIN CHLORIDE IN 5% GLUCOSE, CALCULATED FROM TABLE XXV

Series	Gain in total sugars	Gain in sucrose	Synthetic efficiency	
Glucose	10.425	3.332	31.96	**37.49** ± 2.638
Glucose	12.210	5.254	43.03	
Glucose + B_1	14.263	7.314	51.27	**50.68** ± 0.281
Glucose + B_1	13.098	6.561	50.09	

TABLE XVII

FRUCTOSE AND GLUCOSE PERCENTAGES IN DETACHED ROOTS IN AERATED CULTURE WITH AND WITHOUT THIAMIN CHLORIDE IN 5% GLUCOSE

Series	Fructose	Gain in fructose	Glucose	Gain in glucose
Initial control	**0.899** ± 0.040		**1.546** ± 0.023	
Initial control	**1.152** ± 0.023		**1.364** ± 0.021	
Glucose	**1.362** ± 0.008	0.337	**8.026** ± 0.026	6.571
Glucose	**1.782** ± 0.027	0.757	**7.368** ± 0.047	5.913
Glucose + B_1	**1.421** ± 0.153	0.396	**7.613** ± 0.146	6.158
Glucose + B_1	**1.105** ± 0.025	0.080	**7.557** ± 0.043	6.102

TABLE XXVIII

MOISTURE AND SUGAR PERCENTAGES IN DETACHED ROOTS IN AERATED CULTURE WITH AND WITHOUT RIBOFLAVIN IN 5% GLUCOSE

Series	Moisture	Reducing sugars	Sucrose	Total sugars
Initial control	**90.07** ± 0.081	**1.023** ± 0.055	**1.659** ± 0.065	**2.769** ± 0.014
Initial control	**89.31** ± 0.038	**1.452** ± 0.058	**1.397** ± 0.000	**2.923** ± 0.058
Glucose	**90.41** ± 0.024	**10.248** ± 0.023	**4.781** ± 0.036	**15.281** ± 0.061
Glucose	**90.86** ± 0.162	**11.694** ± 0.013	**6.257** ± 0.021	**18.280** ± 0.009
Glucose + B_2	**90.76** ± 0.124	**11.511** ± 0.028	**8.922** ± 0.050	**20.903** ± 0.024
Glucose + B_2	**89.55** ± 0.048	**10.102** ± 0.011	**9.892** ± 0.067	**20.514** ± 0.059

TABLE XXIX

GAINS IN SUGARS AND SYNTHETIC EFFICIENCY OF DETACHED ROOTS IN AERATED CULTURE WITH AND WITHOUT RIBOFLAVIN IN 5% GLUCOSE, CALCULATED FROM TABLE XXVIII

Series	Gain in total sugars	Gain in sucrose	Synthetic efficiency	
Glucose	12.435	3.253	26.16	**28.40** ± 1.068
Glucose	15.434	4.729	30.64	
Glucose + B_2	18.057	7.394	40.94	**44.13** ± 1.522
Glucose + B_2	17.668	8.364	47.33	

roots, another test was conducted in which each series had two replications, the results of which are presented in Table XXV. Each series had three aerators. The gains in sugars and the synthetic efficiencies are recorded in Table XXVI. The percentages of fructose and glucose are reported in Table XXVII. The results for the synthetic efficiency suggest that thiamin chloride aids synthesis in roots, although the error is high. There is no evidence that thiamin chloride affects the conversion of glucose to fructose. In blades, thiamin chloride has been used in several tests, resulting in some tests in a small increase in synthetic efficiency and in other tests in a small decrease, indicating either that thiamin chloride has no real effect upon synthesis in blades, or that the blades already had enough.

Riboflavin (0.0001 per cent), also called vitamin B_2 or vitamin G, has been used in two tests each with two replications. The results of one of the tests are presented in Table XXVIII. The gains in sugars and the synthetic efficiencies are reported in Table XXIX. The percentages of fructose and glucose are recorded in Table XXX. The synthetic efficiency was significantly greater in the series supplied with riboflavin than in the series with no riboflavin. Similar results were obtained in another replicated test. These results suggest that riboflavin aids synthesis in roots. There is no evidence that riboflavin aids the conversion of glucose

TABLE XXX

FRUCTOSE AND GLUCOSE PERCENTAGES IN DETACHED ROOTS IN AERATED CULTURE WITH AND WITHOUT RIBOFLAVIN IN 5% GLUCOSE

Series	Fructose	Gain in fructose	Glucose	Gain in glucose
Initial control	0		**1.023** ± 0.055	
Initial control	0		**1.452** ± 0.058	
Glucose	**0.358** ± 0.092	0.358	**9.890** ± 0.069	8.653
Glucose	**0.375** ± 0.084	0.375	**11.319** ± 0.071	10.082
Glucose + B_2	**1.552** ± 0.180	1.552	**10.459** ± 0.030	9.222
Glucose + B_2	0	0	**10.102** ± 0.011	8.865

to fructose. In blades, the use of riboflavin was sometimes accompanied by a small increase and sometimes by a small decrease in synthetic efficiency.

Nicotinic amide (0.001 per cent), another member of the vitamin B complex, was supplied to detached roots in two tests each with two replications. In the first test the synthetic efficiency of the roots without nicotinic amide was 43.75 ± 0.653, and with nicotinic amide it was 50.03 ± 0.987. However, in the second test there were no significant differences in synthetic efficiency with and without nicotinic amide. It would therefore seem that nicotinic amide has no significant effect upon the synthesis of sucrose.

Pyridoxin (0.001 per cent), also called vitamin B_6, was used in two preliminary tests with detached roots. In the first test, the synthetic efficiency of the series without vitamin B_6 was 39.74, and with vitamin B_6, 50.71. In the second test, the synthetic efficiency of the series without vitamin B_6 was 66.97, and with vitamin B_6, 73.72. In a test with two replications per series there was no significant difference in synthetic efficiency with and without vitamin B_6.

Ascorbic acid (0.01 per cent), also named vitamin C, was used in a test with roots with two replications per series. The synthetic efficiency without ascorbic acid was 52.92 ± 0.830, and with ascorbic acid, 52.47 ± 0.949.

Water-soluble compounds with vitamin K activity were used in an experiment with detached roots with two replications per series. These compounds were 2-methyl-3-phytyl-1, 4-naphthoquinone and the diphosphoric acid ester of dihydro K_1. The synthetic efficiency without these compounds was 39.26 ± 0.043; with the first compound, 40.54 ± 0.391; and with the second compound, 42.53 ± 0.997.

Phthiocol (0.005 per cent) had no significant effect upon the synthetic efficiency of detached roots.

Folic acid (10 gamma per liter) had no significant effect upon the synthetic efficiency of detached roots.

Of the nine vitamins used in tests with detached roots, seven had no significant effect upon synthesis. Replicated tests with thiamin chloride and riboflavin indicated that these vitamins aid the synthesis of sucrose. Although aeration, thiamin chloride, and riboflavin all aid synthesis in detached roots, they do not enable roots to make sucrose as well as blades, which indicates that some factor necessary for synthesis is still deficient in detached roots.

Summary

This paper deals with the effects of phosphorus, nitrogen, and several enzymes, hormones, and vitamins upon the interconversion of glucose and fructose and the formation of sucrose by detached blades and roots of the sugar cane plant supplied with glucose or fructose in the dark.

Results obtained by growing plants with and without phosphate, as well as by supplying detached blades or roots with phosphate along with glucose in the dark, suggest that phosphate plays a rôle both in the conversion of glucose to fructose and in the formation of sucrose.

Bone phosphatase, which liberates inorganic phosphate from organic compounds, decreased or prevented the formation of sucrose from glucose. This suggests that it is organic phosphorus which is essential for the formation of sucrose.

When plants were grown with different amounts of nitrogen, both the synthetic

efficiency and the activity of invertase were greatest in the plants grown with high nitrogen.

When detached blades were supplied with different amounts of sodium nitrate along with glucose in the dark, their synthetic efficiency was increased by the addition of 100-200 p.p.m. N but greatly decreased by 400-800 p.p.m. N. The conversion of glucose to fructose was also diminished by 400-800 p.p.m. N. But when ammonium sulphate was used instead of sodium nitrate, there was no definite effect upon the synthetic efficiency or upon the conversion of glucose to fructose. These results suggest that supplying a surplus of nitrate to the blade may interfere with the interconversion of glucose and fructose and with the formation of sucrose. This does not apply to plants growing in the field, where nitrate fertilizer is rapidly reduced in the roots.

Supplying blades with "Convertit" ranging from 0.01 per cent to 10 per cent resulted in an increased activity of invertase and a decreased ability to make sucrose from glucose.

Growth-promoting substances (beta indole acetic acid, beta indole butyric acid, indole-3-propionic acid, alpha-naphthalene acetic acid, and cinnamic acid) prevented the conversion of glucose to fructose and the formation of sucrose in detached roots supplied with glucose.

The following vitamins were used in replicated tests with detached roots supplied with glucose in the dark, in aerated culture: thiamin chloride, riboflavin, nicotinic amide, pyridoxin, ascorbic acid, 2-methyl-3-phytyl-1, 4-naphthoquinone, the diphosphoric acid ester of dihydro K_1, phthiocol, and folic acid. Both thiamin chloride and riboflavin, used separately, were found to increase the synthetic efficiency, although the error was high. None of the other vitamins affected synthesis significantly.

Although aeration, thiamin chloride, and riboflavin all aid synthesis in detached roots, they do not enable roots to make sucrose as well as blades, which indicates that some factor necessary for synthesis is still deficient in detached roots.

A Report on 32–8560 at Waialua

By A. C. Stearns*

The agricultural practices employed in the growing of the old standard varieties such as H 109 and Yellow Caledonia are based upon a wealth of accumulated information developed through the years by experimentation and observation. The advent of a new variety invites a re-examination of established practices. This does not imply that a new beginning must be made; basic principles remain applicable regardless of variety. The revisions in practice required by a new variety involve changes in degree; they are not likely to involve a revision of principles.

Nevertheless, gains of considerable economic importance may be affected by skillful adjustment of agricultural practices to varietal requirements. In the following paper the status of 32–8560 at Waialua Agricultural Company, Ltd., is discussed by A. C. Stearns with the object of recording the information which has been acquired thus far at Waialua, and pointing to questions about which more information is needed.

(A. J. M.)

Introduction:

From an agricultural point of view, the arrival and subsequent success of the sugar cane variety 32–8560 represents a milestone in the progress of Hawaiian sugar agriculture. On irrigated, as well as on a number of unirrigated plantations, this variety is giving outstanding yields and is being spread rapidly. 32–8560 is a result of the intensive cane breeding program that has been carried on by the Experiment Station, H.S.P.A.

32–8560 is the outcome of a cross between the Java cane P.O.J. 2878 and the Indian variety Co. 213. The cross was set up on November 24, 1931, when ten tassels of Co. 213 were placed in a large P.O.J. 2878 crossing rack. Thirty-five seedlings were grown from this cross. The plant crop selection was made on September 22, 1932, by A. J. Mangelsdorf and C. G. Lennox. In this first phase of selection, the seedling received the number 32–8560. The first grading given the seedling was "equal-plus." From the original cross, a total of four seedlings was selected in the plant crop and four more in the ratoons. None of the others survived the preliminary testings and 32–8560 was the only one to arrive definitely as a commercial variety.

The development of 32–8560 at Waialua goes back to 1938. It was in that year that the first commercial field plantings were made. The variety had been planted in experiments, but the results were not available and the small original plantings were made on the basis of experimental results being obtained at other plantations

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and in Experiment Station plantings. From the beginning, 32–8560 was observed to be an unusual variety showing many characteristics that were of particular interest to the field production staff and to management. During the late nineteen thirties, it had become increasingly apparent at Waialua that a variety of sugar cane which was better suited to the upland areas was needed. As these original plantings of 32–8560 progressed, the growth characteristics were noted. The large-scale spreading of 32–8560 was soon underway. The program was started: and with each succeeding year, it increased in intensity and scope. The improvement of field layouts and irrigation efficiency was closely associated with the spreading of this new variety.

With the adoption of a new variety on a commercial basis, field staffs and management are confronted with the problem of understanding how to grow properly the new cane to obtain the maximum economic yields. Generally speaking, most varieties vary in their growth characteristics sufficiently so that it is possible to differentiate in various phases of their cultural treatment. The advantages in learning as soon as possible what the growth characteristics are and how the variety should be grown are obvious. In this report it is my intent to summarize all data that pertain to 32–8560 at Waialua in order to aid in making possible a better understanding of this plant.

Planting of 32–8560 at Waialua:

The development of the present acreage of 32–8560 at Waialua is set forth in the following table:

TABLE I

SUMMARY OF 32–8560 PLANTINGS 1938–1942

Year	Total acres planted	Acres planted to 32–8560	Per cent 32–8560 planted	Total cultivated acres	Per cent 32–8560 of total area
1938	2450.12	101.09	4.13	9828.17	1.03
1939	2845.20	1575.83	55.39	10190.60	16.46
1940	1299.43	776.41	59.75	9662.07	25.39
1941	1944.98	1903.84	97.88	9845.71	44.25
1942	2179.35	2179.28	99.99	8945.38	68.77

Total 32–8560 planted 6536.45 acres (without area losses due to war emergency).
Total 32–8560 planted 6151.49 acres (now in crop).

In 1938 there was about one per cent of the area in 32–8560. In 1939 this increased to approximately 17 per cent. By 1940 this proportion jumped to 25 per cent and by the end of 1941, the percentage was in excess of 44 per cent. With the 1942 planting completed, the present area in 32–8560 is 69 per cent of the total area in cultivation. The last large increase is partially due to a sizable decrease in total area under cultivation. Area losses included some 32–8560 area.

The area planted in 1938 represents such a small amount that it can be said that the spreading of 32–8560 to its present acreage at Waialua was accomplished in a four-year period. This probably represents one of the most rapid changes to a new variety to be found in the history of Hawaiian sugar cane agriculture. If it is possible in the years 1943 and 1944 to complete our scheduled planting programs, we shall be very near to a total cultivated area that will be nearly 100 per cent 32–8560.

What this has meant and will mean to the economy of the Company can be ob-

served in connection with the summary of the yields of 32–8560 through 1942 as shown in Tables VII through X.

Germination and Type of Seed:

The germination of 32–8560 is not too different from that of other varieties. 32–8560 is subject to the same effects of source and type of seed, soil preparation, soil type, time of start, depth of covering, soil moisture as related to the first irrigation and soil temperatures, as well as the effects of seed treatment (handling of seed, dipping with fungicides, elapsed time from cutting of seed to planting, etc.).

In the many plant fields of 32–8560 that have been started at Waialua since 1938, it has been generally observed that the seed germinates in a very satisfactory manner. The plant field stands have been quite even and usually all germination takes place within a month from time of planting. Under favorable conditions, germination is well underway eight to ten days after planting. It proceeds at an increasing rate until fifteen to twenty days after planting and then levels off. On the basis of germination tests that have been conducted in the field, we obtain from 75 per cent to 90 per cent germination based on the number of seed piece eyes actually planted. As will be noted under comments on replant, the amount of replant in 32–8560 fields has been quite low. As was mentioned above, the type of stand that is obtained in plant fields is quite even, although we have noted instances where the condition of the seed used has influenced the evenness of stand. Body seed has been used almost exclusively and has given satisfactory results. Until the 1942 planting season, short seed was used (about 12-15 inches in length). In 1942 it was necessary to handle seed with rope slings instead of burlap bags. It was found that a longer seed piece (20-30 inches) was needed to enable the effective use of slings. The longer seed, in most cases, has given satisfactory stands and the germination has been fairly good.

When planting in the warm summer months, it has been found that it is not necessary to dip seed in Ceresan to obtain good germination; however, during the winter months when soil temperatures are low, it has been found to be an effective and worthwhile practice which aids in obtaining good germination.

Stands of 32–8560, although more rapid in initial growth than H 109, do not appear to grow rapidly until about three to four months after planting. This is a clear-cut phenomena and has been observed in practically all plant fields.

No special effort has been made to develop seed for planting purposes. We have usually selected plant field areas that are from seven to ten months of age and where the prospective seed is of good quality. Although there has been a feeling in some quarters that seed areas should receive careful nitrogen fertilization and irrigation control, we have made no definite move in this direction. Unless seed areas are planned for far in advance, it is not possible to do this effectively. As long as care is exercised in the selection of the seed areas, past experience would indicate that satisfactory results can be obtained.

The seed piece characteristics of 32–8560 are such as to make for easy handling. The eyes are fairly flat and are not damaged to any great extent in transit. Long internodes sometimes make for few eyes per seed piece. This can be considered to be a disadvantage indicating that seed areas should not be allowed to grow too rank. Seed from rank, succulent cane is also subject to more rapid deterioration when placed in contact with the soil.

The amount of seed used per acre in plant fields varies from 50 to 70 bags or bundles per acre depending on the amount of overlap and the size of seed pieces. Size in this instance refers to diameter of the seed piece. Of course, the length of seed piece as related to short seed versus long seed would likewise affect the number of bags or bundles used.

Soil type affects germination to the extent that in adobe soil types where the surface cakes badly after irrigation, the germination is sometimes slower. In the red residual soil types of the Koolau slope, the soil is friable in nature and with other conditions being equal, the rate of germination is usually more rapid than where heavy soils and poor aeration are encountered, as in some of the makai fields.

To insure a favorable germination and stand, the first irrigation follows planting as rapidly as possible. Subsequent irrigations follow at a three- to seven-day interval depending on conditions. As the stand progresses, the interval of irrigation gradually increases up to ten to fourteen days depending on moisture conditions at the time. This is fairly typical of young stands of cane up to six months of age.

Replant—Plant and Ratoons:

Due to the large amount of heavy mechanical equipment that moves through a cane field under present-day operating conditions, the effect on the amount of replant required is evident. This is particularly true of H 109 fields. 32–8560, due to its strong growing characteristics, appears to be a variety that is better suited to the rugged treatment that fields receive under present conditions.

It has been our experience that the amount of replant required in 32–8560 plant fields usually varies between one and two bags per acre. During 1942 in fields where soil preparation has been below optimum and where long seed has been used, we have had instances where replant in plant fields has gone as high as four to six bags per acre. This, however, is considered to be abnormal.

In ratoons of 32–8560 we have found that the amount of replant per acre varies from two to five bags. This refers particularly to first ratoons. In certain instances, second ratoons of this variety have required slightly more than this. 32–8560 is a vigorous ratooner and closes-in more rapidly than plant cane, as would be expected. It is necessary to get the replant in as soon as possible after starting a field; otherwise, the shading-in will eliminate much of the replant as an effective part of the production potential of the field. These replant data in ratoons are based on observations in mechanically harvested fields. All replant seed is dipped in Ceresan solution.

Cultivation:

In many respects the growing characteristics of 32–8560 have a definite appeal to those concerned with the cultivation of the variety. In plant cane, due to its upright growth characteristics, the variety appears to be slow in closing-in as compared with 31–2510, 31–1389 or 31–2806. This is true; however, its yielding ability so overshadows these three mentioned varieties that they cannot be considered in the same class with 32–8560 at Waialua. This openness in plant cane makes 32–8560 somewhat comparable with H 109; however, actually the appearance of millable cane comes earlier with 32–8560. Data indicate first-season growth of

32–8560 to be considerably stronger than H 109. Indications are that ratoons of 32–8560 will be much cheaper to cultivate than the plant crops.

32–8560 due to its vigorous growth is particularly well adapted to mechanical cultivation. Its upright growth can be an advantage here in allowing a close approach to the row of cane. Disc line reshapers and weeders have been used effectively. It has been reported from Ewa that 32–8560 in some instances assumes a partial recumbent form of growth. This has been noted in a minor way at Waialua.

Probably one of the most important phases of field cultivation with particular regard to weeding (hand, spray, and mechanical) is the coordination of the operations. For example, this ties in directly with fertilization where a policy of clean fields prior to fertilizing exists. The basic policy of clean fields prior to fertilizing is sound. The emphasis intended here is that in order to maintain fertilization at the optimum time of application, it is necessary to have a strong coordinated action on the part of field supervision to have the right fields clean at the proper time.

Under Waialua conditions the openness of 32–8560 has not been considered a serious factor. On other plantations this characteristic is of some importance. For instance at Kohala in the mauka areas, the openness is a factor affecting weed control. Other varieties affording more satisfactory weed control and which give comparable yields come into use under such conditions.

Pali-pali and line reshaping operations as they affect 32–8560 ratoons are of importance, particularly in their bearing on irrigation. This ties in closely with the planting and layout of a field since present line reshaping implements are not capable of changing the grade of the original line. To avoid variable growth in ratoons which is attributable to grade of line, shape of line and length of line, and the quality of irrigation resulting from such irregularities, it becomes increasingly important that the layout and planting of fields be closely controlled and supervised. Layout and planting affect cultivation operations as well as irrigation. Both should be developed in such a manner as to aid most effectively in cultivation and irrigation operations.

The quality of plowing and field preparation has been observed to have an effect on subsequent growth and cultivation operations. Factors affecting these operations, particularly labor and equipment are not always controllable; however, it is recognized that good field preparation is worthwhile and has a favorable effect on the crop and cultural operations.

32–8560 and Irrigation Practice:

Irrigation at Waialua is based primarily on control effected through the use of the soil moisture method as adapted and developed by H. R. Shaw and J. Swezey, as well as on experience gained in the irrigation of cane in the several soil types and conditions that exist on the plantation. No special effort has been made to irrigate 32–8560 in any prescribed manner except that good irrigation is stressed, *i.e.*, adequate penetration of water in all parts of each line of cane. Although it has been propounded that 32–8560 is a drought-resistant variety and does not require as many rounds of irrigation as, for example, H 109, we have continued to irrigate it in much the same manner as we do our other varieties.

Based on yields obtained in the past two crops, it would seem that irrigation (a primary control factor in yields at Waialua) was not deviating too far from

optimum. There are several reasons for this as far as 32–8560 is concerned. First, practically all yields are reported from plant fields. Plant fields, due to soil preparation, offer a tilth that affords good conditions for an optimum penetration of water in the cane line. Second, with new plant field installations, field layouts were considerably improved. It is felt that irrigation, as such, has not had a deleterious effect on the yields reported here, except in the Koolau mauka group, because conditions affecting irrigation have been very near to optimum. This refers particularly to yields from plant fields. What will be experienced in the ratoons of 32–8560 may be more closely related to irrigation than the plant field yields. Due to good soil conditions, plant fields overcome some of the irregularities that exist in grade of line and shape of line; however, in ratoon fields where the soil has become quite packed after two years of irrigation, the term tilth no longer applies to the soil. In the ratoon crops, the soil does not permit easy and rapid penetration of water due to the hardness of soil, particularly if grades, shape and length of line are not optimum. In combination, these factors cause irregular distribution of water in the line. It is felt that if comparable irrigation can be obtained in ratoon fields as in plant fields, yields will be maintained reasonably well.

TABLE II

SUMMARY OF IRRIGATION—32–8560 (1941–1942 CROPS)

Field group	Year	Age	Irrigations		T.S.A.M.	Avg. ac. per man-day	Avg. ac. in.* per ac. per rd.	Acres
			Number	Per mo.				
Koolau Mauka	1941	22.35	34.7	1.55	.644	9.93	5.98	624.00
	1942	23.00	31.1	1.35	.570	7.42	6.52	576.66
Koolau Makai	1941	21.08	32.3	1.48	.601	6.50	5.64	245.18
	1942	23.00	34.1	1.48	.545	5.94	6.76	323.30
Waianae	1941	20.39	28.3	1.39	.552	6.58	7.49	403.73
	1942	20.99	32.7	1.56	.530	7.05	8.44	152.43
Plantation	1941	21.51	32.3	1.50	.610	8.28	6.38	1322.91
	1942	22.71	32.2	1.42	.557	6.91	6.87	1052.39

* Acre-inch figures are based on gross water deliveries.

In Table II the irrigation applied to the 1941 and 1942 crops of 32–8560 is summarized. Among the field groups there has been a slight variation in number of rounds applied. The averages for the two crops are quite comparable. Although the Koolau groups have somewhat higher average number of rounds, there were fields in these areas that actually suffered from a lack of water in the two crops. Considering the limitations of water supply, it is felt that irrigation of the 32–8560 fields was as optimum as possible under operating conditions at the time.

Acre inches of water applied per round are, in general, somewhat below the plantation average. This is due to the fact that most of the 32–8560 fields have been located on the Koolau slope where soil conditions permit the use of less water per round. The Waianae group is low considering that acre inches are generally high in this area. New and more effective field layouts have contributed to more efficient use of water and labor.

With the spreading of 32–8560 there has been an increase in labor efficiency as associated with irrigation. The continued spread and improvement of Waialua flume and field layouts is primarily responsible for this increased man-day performance.

The following tabulation indicates the rate of improvement since 1938 when 32–8560 made its appearance:

IRRIGATION SUMMARY—MAN-DAY PERFORMANCE

Year	Average acres irrigated per man-day
1942	7.07
1941	6.46
1940	6.16
1939	4.62
1938	3.08

Thus far Waialua has been unable to associate any decrease in yield with the number of acres irrigated per man-day. However, this is a point that must be watched because maximum yields are the objective rather than high man-day performance achieved at the expense of thoroughness in irrigation. Quality irrigation must be maintained.

In the Koolau mauka group of fields, it appears that the reduced number of rounds of irrigation per month in the 1942 crop may have caused a reduction in sugar per acre month yields. Since there is not much differential in age and knowing that we did experience a water shortage in many of the fields harvested in the 1942 crop in that area, there is probably a significant effect of lack of irrigation on yields in this field group.

The Koolau makai group has a reduced yield in 1942 as compared with 1941 (T.S.A.M.); however, this is probably due more to age of crop and the particular fields harvested rather than to irrigation since a water shortage was not acute in this area.

The Waianae group of fields received adequate irrigation in both 1941 and 1942, although the intensity of irrigation was greater in 1942. Due to the small acreage of 32–8560 harvested in this field group in 1942, the effect of individual fields might be dominant and it is questioned whether the 1942 yield average in this area is truly representative. Irrigation is not a limiting factor in this area as related to water supply. In the poorly drained fields it is possible to overirrigate. It has been observed that 32–8560 responds readily to drainage. The Kawaihapai fields afford an excellent example of this.

32–8560 in ratoon crops is particularly sensitive to inadequate irrigation. In first ratoon fields where the grade of line, shape of line, length of line, flow control,* and soil condition have not been conducive to adequate penetration, 32–8560 is visibly affected. Sharp lines of variable growth have been noted. This is associated with fertilizer distribution, too; however, inadequate irrigation is a principal cause. The tendency of 32–8560 toward rapid rank growth where conditions are optimum undoubtedly causes this differential between good and poor growth areas to appear serious. However, it is felt that 32–8560 in the poor areas is still better than other varieties that have been grown in the same poor spots. Steps are being taken to minimize the range of variation caused by those factors mentioned above.

Ripening of 32–8560:

The so-called ripening or drying off of fields prior to harvest is a phase of cul-

* Flow control refers to the control of water going into individual furrows.

tural practice which is decidedly weak. The difficulty in predicting weather for even a few months in advance makes the scheduling of ripening a difficult problem. Fields at Waialua vary in their environmental factors (soil, drainage, rainfall, and temperature) that affect ripening and sound differential treatments are difficult to attain.

Ripening practice is felt to be an important part of the growing of 32–8560. For that reason considerable study has been made in an attempt to develop correlations with yields and juice quality that could be practically applied in terms of field practice.

On the basis of data available, we are unable to establish a positive relationship between the number of days water is off prior to harvest and the juice quality obtained at harvest. Due to the uncontrollable factor of rainfall, it was felt that perhaps the number of days the fields were below wilting point during the ripening period would permit a better correlation; however, here again no reliable trend was noted. It, of course, makes a difference as to when the days below wilting occur. If they should occur early in the ripening period and adequate moisture is available in the field at harvest, the probability would be that other than optimum juices would be obtained.

To check this point the number of days below wilting point directly prior to harvest was studied. Here the result was somewhat better. Although we are unable to state the exact number of days below wilting point that should be allowed to attain good juices (nor would we be able to control them if we did know), it is evident in fields where good juices have been obtained that the soil should go below the wilting point directly prior to harvest to obtain the best juices. The total days of ripening actually mean very little. The ripening time that really counts is the period directly prior to harvest. Since the uncertainty of rain makes it impossible to set up a precision control on ripening, the best that can be done in the way of intelligent field practice is to consider each field individually, weigh the time of harvest against the season, age of crop, soil moisture (such as drainage problems) and set a ripening period that will allow for optimum ripening—average weather conditions permitting.

The leaves of 32–8560 do not change in color during ripening to the same extent as H 109. Due to the dark green color that is characteristic of the variety, it appears to be evident that when 32-8560 looks dry—it is too dry for maximum yields. It appears that 32–8560 should not be brought to a stage of drying-off where it appears as yellow in color as H 109. We have had instances where a field was dark green in color for an April harvest. The drying-off directly prior to harvest appeared optimum for this time of harvest (30 days below wilting) and a 7.68 juice quality was obtained.

A phase of ripening that should be considered and developed is the treatment of the field prior to ripening. With a rank-growing variety such as 32–8560, there is the possibility of deterioration. In addition there is the danger of abruptly taking the water off of a crop when it is in a state of rapid growth. The conditioning of a field for ripening, particularly for the summer and fall harvest months is one that deserves consideration. A field that has had extended irrigation intervals for a 3- to 5-month period prior to the initiation of ripening would be hardened and would be in a better condition to withstand the rigorous treatment imposed on a field that is ripened during the hot summer months. This, in combination with shorter ripening during

this period, should be a step forward in ripening policy. This would also afford an opportunity to control the high rate of growth during the harvesting season. (Note Fig. 1 on Average Weekly Growth by growing seasons.) This would, as noted elsewhere in this report, bring the cane in better condition to harvest and would possibly improve the juice quality obtained.

32–8560 and Fertilization:

Under Waialua conditions fertilizer represents one of the more important factors available for the control of growth and sugar production. This is particularly true with 32–8560 for here is a variety that appears to be sensitive to excessive amounts as well as to inadequate amounts. This refers particularly to nitrogen fertilization. Over fertilization with nitrogen results in rapid rank growth, that is subject to poor condition and juice quality that is not optimum. Although yields obtained thus far indicate that fertilization has been adequate, it is felt that Waialua still has progress to make in finding both amounts and time of applications that will increase the effectiveness of 32–8560 fertilization practice. In general, the trend is toward reduced amounts of nitrogen in plant crops. Ratoons in some instances may need increased amounts.

Nitrogen: Nitrogen fertilization for 32–8560 was originally based on an approximate 200–210 pounds per acre for H 109 with a 20-pound per acre reduction for 32–8560. Due to the growth characteristics of 32–8560, this was felt to be a safe reduction. Experiments that were subsequently harvested indicated no significant gains in sugar over 150–160 pounds per acre. Nitrogen field practice has continued between 180–190 pounds per acre.

On the basis of observation made, thus far, it appears that Waialua may be somewhat high in nitrogen fertilization of 32–8560 plant crops. Where nitrogen is evenly applied in experiments, 160 pounds per acre appears to be sufficient. This would probably result in slightly lower tonnages; however, juice quality and economic sugar production would undoubtedly benefit.

Although Waialua has no experimental evidence to substantiate this point, it does appear that the ratoon crops of 32–8560 do not show the growth or color that is characteristic of plant crops of the variety. On the basis of observation of fields and yields, it appears that it may be profitable to reduce the nitrogen amounts from 180–190 to 160–170 pounds per acre in plant crops of 32–8560 (depending on age and cropping). The 20 pounds saved on the plant crops could probably be applied to advantage on certain ratoon fields where there is fragmentary evidence that the ratoon yields may decrease due to a shortage of nitrogen. Due to the difficulties found in the obtaining of even fertilizer distribution within a field, it is sometimes felt that the importance of a 20-pound or even a 40-pound application of nitrogen can be overemphasized in research studies. Field practice in many instances is confronted with variations in plant food distribution that exceed the differentials mentioned. There is as much a need for even fertilizer distribution as there is for the control of fertilizer amounts when these amounts are within 20 to 40 pounds of the optimum.

Mechanical or hand methods of nitrogen application should be used if possible. All ammonium phosphate applications should be applied by hand or mechanical means, not by water. Fertilizer in this form does not go into solution readily and water applications are subject to considerable variations in actual distribution. Im-

provement of soil tilth by subsoiling in ratoons should be a step toward better irrigation in ratoons and as a result more satisfactory plant food distribution where fertilizer is applied by water. 32–8560 is as responsive if not more so to adequate amounts of plant food and water as the older varieties.

Nitrogen applications in the past three crops of 32–8560 have been as follows:

TABLE III

32–8560—SUMMARY OF NITROGEN FERTILIZATION BY SEASON AND FIELD GROUPS 1940–41–42 CROPS

(Pounds Per Acre)

Field group	1940 First season	1940 Second season	1940 Total	1941 First season	1941 Second season	1941 Total	1942 First season	1942 Second season	1942 Total
Koolau Mauka ...	168	...	168	84	105	189	76	117	193
Koolau Makai	111	79	190	34	156	190	127	60	187
Waianae	...	...	...	25	172	197	91	88	179

There has been very little variation in the general nitrogen treatment of 32–8560 except as developed by differences in cropping. In general the amounts have been held about 20 pounds per acre less than comparable H 109 fields.

Following is a rule-of-thumb basis of determining the approximate amounts of nitrogen to be applied during the first and second season of crops at Waialua based on the time of start and the time of harvest:

TABLE IV

32–8560—APPROXIMATE AMOUNTS OF NITROGEN BY MONTH OF START

(Pounds Per Acre)

Month of start	First season	Second season	Total
January, February, March	147	42	189
April, May, June................	126	63	189
July, August, September.........	84	105	189
October, November, December....	63	126	189

Until such a time as we are able to use effectively the plant as an index of its plant food requirements, a basis as given above must be followed in some form. Table IV as given is approximate, as each field received individual attention as to its fertilizer schedule. The general pattern as indicated is based largely on past experience and field experiments. We are somewhat above the maximum indicated by experiments for plant crops of 32–8560. Realizing the variations introduced by water applications of fertilizer, this margin over the maximum as indicated by experiments, has constituted a safety factor.

Phosphate: The use of phosphate in 32–8560 fields has followed the practice used for H 109 and other varieties. In general approximately 100 pounds of P_2O_5 is applied per acre; however, there are instances where soil analyses have indicated the P_2O_5 content to be low and increased amounts have been applied to the field in question. A large amount of soil data pertaining to P_2O_5 has been accumulated and it serves as a guide in determining amounts to be applied. Thus far, in the growing of 32–8560, we have had no serious indications of P_2O_5 shortages. There are pali areas of poor soils where spot fertilization is necessary. Phosphates to be most effective should be applied either by hand or mechanically, and preferably below the surface, to achieve the best results. We do this in our planting operation where super phos-

phate is applied by machine and is rather well covered in the seed-covering process. In plant crops phosphates are applied at time of planting. In ratoon crops phosphate is usually applied a month to six weeks after the crop is started.

TABLE V

32–8560—SUMMARY OF P_2O_5 FERTILIZATION FIELD GROUPS 1940–41–42 CROPS

(Pounds Per Acre)

Field Group	1940	1941	1942
Koolau Mauka	105	120	100
Koolau Makai	102	88	103
Waianae	...	87	104

Potash: Potash fertilization in relation to 32–8560 has conformed very closely with general plantation practice. This amounts to about 122 pounds per acre of K_2O per crop. In some areas where soil analyses indicate this element to be low, the amount is raised to 183 pounds per acre. In many of the makai fields where the K_2O level is quite high, the amounts are adjusted downwards accordingly. In general all K_2O is applied with the second application of nitrogen. That is, in plant crops, K_2O would be applied when the cane is 4–6 months of age and in ratoons when the cane is 3–5 months of age. Although not always true, this practice tends to bring a field into its first winter with ample K_2O to draw upon and with a moderate supply of nitrogen. It has been suggested by the Experiment Station that the K_2O/N balance in the winter months should be in favor of K_2O and low on the nitrogen side. Such a practice has not been definitely confirmed under Hawaiian conditions as yet. Our practice approaches the suggested one in many cases.

K_2O is applied in the form of muriate of potash. Applications in the past few years have been made principally by water. Muriate of potash dissolves readily and can be applied by water effectively as long as irrigation practice is good.

TABLE VI

32–8560—SUMMARY OF K_2O FERTILIZATION BY FIELD GROUPS FOR 1940–41–42 CROPS

(Pounds Per Acre)

Field Groups	1940	1941	1942
Koolau Mauka	122	169	134
Koolau Makai	110	123	138
Waianae	...	123	122

32–8560 and Growth Rates:

On the basis of observation and yield data collected, 32–8560 has proved itself to be a strong grower. Fig. 1 on Average Weekly Growth by starting, growing, and harvesting year indicates the growth picture of 32–8560 to be much the same as H 109 except that the rate for any given month is substantially greater with 32–8560. This has been assumed to be true; however, this is the first evidence that has been developed with Waialua data to substantiate our observations.

These growth data are of interest and if interpreted properly can be of assistance in planning cropping, fertilization, irrigation, and perhaps planting with the objective of effectively using time and growth to realize the maximum production of sugar with 32–8560.

AVERAGE WEEKLY GROWTH
32-8560 AND H 109
40-41-42 CROPS

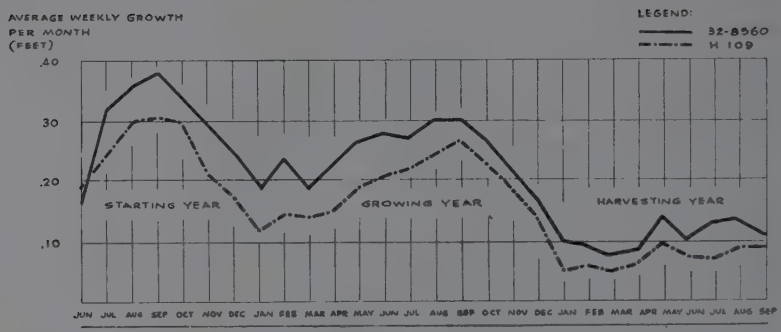

Fig. 1

For example, effective cropping makes use of various combinations of growing time, growth and production factors to obtain the greatest sugar yields possible. The trends shown in Fig. 1 can be of definite assistance by indicating the periods when the most growth can be anticipated. If a field of 32–8560 is started in June and scheduled for harvest 22 months later in April, it is apparent that the growth in the second January, February, and March may not be sufficient to justify the extra time given to the particular field. It might be more profitable from the standpoint of growing time to harvest in January or February. A compensating factor for the loss of growth could be an expected improvement in juice quality. The growth of 32–8560 from May to September in the harvesting year indicates that control is needed to reduce the growth rate for fields harvested during this period if the sucker population is to be minimized and juice quality improved. Various interpretations can be made with data of this type. The curves shown in Fig. 1 are subject to change and modification as more data are collected. They reflect the trends in 32–8560 growth as compared with H 109 under a specific combination of growth and cropping conditions.

Interpreting these growth data in terms of fertilization, it appears that first-season applications of nitrogen should be applied early in the crop to permit the full recovery of growth that is possible in the starting year. Losses in growth due to late and poorly timed applications could be considerable. Second-season applications at Waialua have a better chance for rapid absorption if applied in March and April rather than in January and February of the growing year.

These data may also have a bearing on irrigation practices. During the starting year and growing year, irrigation should be maintained at an optimum rate with the possible exception of the first winter season when extended intervals would be in order due to the reduced rate of growth. It appears possible in the harvesting year to extend intervals. Growth during this period is low and controlled irrigation would result in labor economics as well as increasing the probability of putting fields in better condition for harvest. Juice quality would undoubtedly be improved.

Although 32-8560 does better with late planting than other varieties we have

spread, experience would indicate that late planting should be avoided when possible. More sugar per unit of growing time can be obtained by planting in months that make possible the greatest recovery of growth.

Returning for a moment to cropping, these data represent average growth. By a study of individual fields, the growth rates would indicate to a considerable extent, in conjunction with yields, what trends future cropping should follow. I have attempted here to suggest various ways in which data of this type can be of assistance in guiding field practice.

Yields of 32–8560:

Soil Type and Elevation as Factors Affecting Yield: In a study of 32–8560 that was made last year on the basis of yields to that time, three large field groups were set up. The purpose in doing this was to determine, if possible, the effect of elevation and soil type on the yields of this variety. The field groups are identified as follows:

GROUPING OF FIELDS

Koolau Mauka (Kemoo, Helemano, Opaeula, Kawailoa and Waimea Divisions above 300 feet)
Koolau Makai (Kemoo, Helemano, Opaeula, Kawailoa Divisions below 300 feet)
Waianae (Ranch and Kawaihapai Divisions)

Koolau refers primarily to the red residual soils that occur in fields on the Koolau slope and which comprise practically all the soil in that area. In the fields constituting the Waianae soils, the principal types vary from alluvial to sedimentary soils and are made up of silty clay loams, sands, and rocky alluvials. The Waianae group includes elevation from sea level to 300 feet. A small area of brown residual soils is present in this latter group.

In last year's study, trends in yields were observed which were felt to be associated with elevation and soil type. The same field groups are being used in this report.

Table VII indicates that the five-crop mean yields of the fields harvested in 1942 are somewhat higher than the fields harvested in 1941. Per cent gains are thus greater for the 1941 32–8560 crop in the Koolau mauka field groups. The factor of water shortage had some effect on the 1942 yield because one would expect the 1942 fields to give higher yields based on the past performance of the fields involved. Since 1940, 1941, and early 1942 were quite dry, there may have been an accumulative effect of deficient rainfall on yields. The age differential between the two crops is not sufficient to cause the difference in yield. Juice quality was not as good as in previous crops but not bad considering the tonnage of cane obtained. This mauka group of fields was formerly the poor yielders. 32–8560 has completely changed the picture and this group of fields now represents the best producing areas at Waialua.

The five-crop mean yields of the Koolau makai fields harvested in 1941 and 1942 are quite comparable. The per cent gains of fields in the 1942 crop compare favorably with the 1941 fields in T.C.A., T.S.A., and T.C.A.M. 1941 32–8560 fields were better in T.C. T.S. and T.S.A.M. Age of crop in 1941 undoubtedly caused a more favorable sugar per acre month figure for that year. Cane and sugar per acre month figures in terms of per cent gain over previous yields are not quite as satisfactory as those in the Koolau mauka group.

TABLE VII

SUMMARY OF FIELD GROUP YIELDS—COMPARING 32–8560 YIELDS IN 1941 AND 1942 WITH THE 5-CROP AVERAGE YIELDS IN THE SAME FIELDS

Yields with age and area data	Koolau Mauka—Field group						Koolau Makai—Field group						Waianae—Field group					
	1941 32–8560 yields	5-crop* average yields	% + or −	1942 32–8560 yields	5-crop average yields	% + or −	1941 32–8560 yields	5-crop* average yields	% + or −	1942 32–8560 yields	5-crop average yields	% + or −	1941 32–8560 yields	5-crop* average yields	% + or −	1942 32–8560 yields	5-crop average yields	% + or −
T.C.A.	105.44	74.51	+42	102.45	78.96	+30	99.63	79.06	+26	106.60	79.02	+35	95.64	78.00	+23	86.95	88.91	— 2
T.S.A.	14.40	10.47	+38	13.12	10.69	+23	12.66	10.31	+23	12.53	10.31	+22	11.27	10.32	+ 9	11.01	11.76	— 7
T.C./T.S.	7.32	7.12	— 3	7.81	7.39	— 6	7.87	7.67	— 3	8.51	7.53	—13	8.49	7.56	—12	7.90	7.56	— 4
T.C.A.M.	4.72	3.14	+50	4.45	3.37	+32	4.73	3.48	+36	4.63	3.54	+31	4.69	3.45	+36	4.14	3.77	+10
T.S.A.M.	.644	.441	+46	.570	.456	+25	.601	.453	+33	.545	.462	+18	.553	.457	+21	.525	.498	+ 5
Age	22.35	23.73	—	23.00	23.44	—	21.08	22.75	—	23.00	22.32	—	20.39	22.58	—	20.99	23.60	—
Area	674.00	4,314.56	—	576.66	4,674.78	—	245.18	770.14	—	323.30	1,516.71	—	403.73	1,264.44	—	152.43	573.27	—

* Most yields are based on a five-crop mean; however, where five crops were not available for some fields, a three- or four-crop mean was used. The 1941 and 1942 32–8560 yields are compared with the mean yields of the same field prior to the planting of 32–8560.

Table VII shows quite a difference in the prior mean yields of the Waianae fields harvested in 1941 as compared with 1942. This naturally gives the 32–8560 harvested in 1941 a considerable advantage in per cent gains as compared with the 1942 crop. Due to the higher yields of previous crops in this group, 32–8560 does not show the large gains in yields that are indicated in the Koolau mauka and makai groups. Still, the gains are sufficient to justify the planting of 32–8560 in makai areas. At the same time we are continuing to search for a lowland variety that is even better suited than 32–8560 to the environmental conditions in this area. Due to the small number of acres harvested in 1942, the individual fields undoubtedly had a dominant effect on yields and the averages as given are probably not representative of the entire area.

As was indicated in last year's study, the Koolau mauka fields above 300 feet elevation showed the greatest per cent gains over previous yields in the same fields, as well as having the highest sugar per acre month values for 32–8560 as compared with the other two groups. The Waianae group which constituted the most productive fields has now exchanged its rating with 32–8560 in the mauka fields. This indicates that H 109 was much better adapted to the lowlands and that in the mauka areas that variety was out of its element. For this reason the gains for 32–8560 when expressed in per cent are naturally higher in the mauka areas. However, actual mean T.C.A., T.S.A., T.C.A.M. or T.S.A.M. as shown in Table X substantiate the superiority of the Koolau fields in growing 32–8560. Considering the average yields of these field groups, there appears to be an effect of soil and elevation on yields Since these yield data are made up principally of plant crops, which are usually better than ratoons at Waialua, it will be particularly interesting to compare yields after sufficient ratoons have been harvested to make possible a better comparison with past yields. All 32–8560 fields included in this study were mechanically harvested. Previous yields in the same fields were handled principally by the hand-cut and hand-load or machine-load method.

Table IX summarizes the per cent gains and losses. The Koolau mauka group is superior as a location for growing 32–8560 on the basis of per cent gains over previous yields in the same fields.

Table X indicates that the superiority of yields in the Koolau mauka group is not only expressed in per cent gains over previous yields but also in actual comparison of yields. In both 1941 and 1942 there was a downward trend in sugar per acre month figures from mauka to makai. In 1941 cane per acre month did not vary materially in the three groups. In 1942 there was slightly more variation; however, other than for the fact that cane production was lowest in the makai group, no particular trend is in evidence. The plantation summary brings out the decrease in yields obtained in the 1942 32–8560 fields as compared with the 1941 yields.

The data in Table X point out that the greatest gains are to be made with 32–8560 in our mauka and makai fields on the Koolau slope. Attention is also drawn to the fact that 32–8560 in the Waianae group of fields requires careful study and care in its culture to obtain the most possible from a variety that is not too well adapted to these conditions, even though it does give evidence of being better than previous varieties grown in this same area.

Record Yields of 32–8560: 32–8560 has set field records of some sort in practically every field in which it has been planted. Thus far, Opaeula 5A holds the pro-

duction record on cane having produced 136.17 tons of cane per acre. This same field holds the record on tons sugar per acre having yielded 16.20 tons of sugar per acre. The best juice quality to be obtained in a 32–8560 field is from Kemoo 2B where a quality of 6.71 was obtained. Waimea 5 in a short plant crop harvested in 1940, holds the record on tons cane per acre month. The figure here was 5.79 tons of cane produced per acre month. Helemano 11 which was harvested in April of 1941 at an age of 20.97 months, set a record of .708 ton sugar per acre month that still stands as the record yield of 32–8560 at Waialua, as well as the all time plantation record for a field containing 179.00 acres.

The magnitude of these record yields indicates to some extent the possibilities in growing this variety. There is a real challenge presented in that the maximum economic yield of sugar should be the goal in each field.

TABLE VIII

32–8560—SUMMARY PLANTATION YIELDS COMPARING 32–8560 YIELDS IN 1941 AND 1942 COMBINED FIELD GROUPS

Yields with age and area data	1941 32–8560 yields	5-Crop average yield	% +or—	1942 32–8560 yields	5-Crop average yield	% +or—
T.C.A.	101.37	75.76	+34	101.48	79.82	+27
T.S.A.	13.12	10.42	+26	12.63	10.74	+18
T.C./T.S.	7.72	7.27	— 6	8.03	7.44	— 8
T.C.A.M.	4.71	3.24	+45	4.47	3.44	+30
T.S.A.M.	.610	.446	+37	.556	.463	+20
Age	21.51	23.38	—	22.71	23.20	—
Area	1,322.91	6,349.14	—	1,052.39	6,764.76	—

TABLE IX

32–8560—SUMMARY OF PER CENT GAINS AND LOSSES

	Koolau—Mauka 1941	Koolau—Mauka 1942	Koolau—Makai 1941	Koolau—Makai 1942	Waianae 1941	Waianae 1942	Plantation 1941	Plantation 1942
T.C.A.	42	30	26	35	23	— 2	34	27
T.S.A.	38	23	23	22	9	— 7	26	18
T.C./T.S.	— 3	— 6	— 3	—13	—12	— 4	— 6	— 8
T.C./A.M.	50	32	36	31	36	10	45	30
T.S.A.M.	46	25	33	18	21	5	37	20

TABLE X

32–8560—SUMMARY OF T.C.A.M. AND T.S.A.M. YIELDS—1940–1941–1942

Crop	Koolau Mauka T.C.A.M.	Koolau Mauka T.S.A.M.	Koolau Makai T.C.A.M.	Koolau Makai T.S.A.M.	Waianae T.C.A.M.	Waianae T.S.A.M.	Plantation T.C.A.M.	Plantation T.S.A.M.	Total area
1940	5.24	.561	4.99	.587			5.19	.566	292.07
1941	4.72	.644	4.73	.601	4.69	.553	4.71	.610	1322.91
1942	4.45	.570	4.63	.545	4.14	.525	4.46	.556	1052.39
Ttl. average	4.67	.606	4.72	.577	4.45	.541	4.66	.584	2667.37

Some Trends of Factors Affecting Cropping:

The proper cropping of a variety is dependent upon a number of factors. One thing certain is that optimum cropping is usually available for only a portion of the total fields in a crop. However, the possibility of cropping all fields to advantage and making the best out of each particular season through which a field passes in reaching maturity is always present.

It is essential to know something about the variety in terms of the proper time to start a crop, the range of age when maximum yields can be expected, and the month of harvest, which in combination with optimum age will give the most effective yield. Although all factors affecting growth are cropping factors, the phases discussed here refer principally to per acre month yields as related to time of start, age at harvest, time of harvest, and juice quality as related to month of harvest, as well as age.

Limitations of operations make it impossible to start and harvest all fields at the most optimum time for the best quality of juice and maximum sugar yields. Effective cropping requires continual analysis so that 32–8560 can be made to produce the maximum economic yield of sugar consistent with the time of start, time of harvest, and age of crop involved.

The data that Waialua have available for a study of the cropping factors of 32–8560 are limited to forty-five fields. These have been harvested over the past

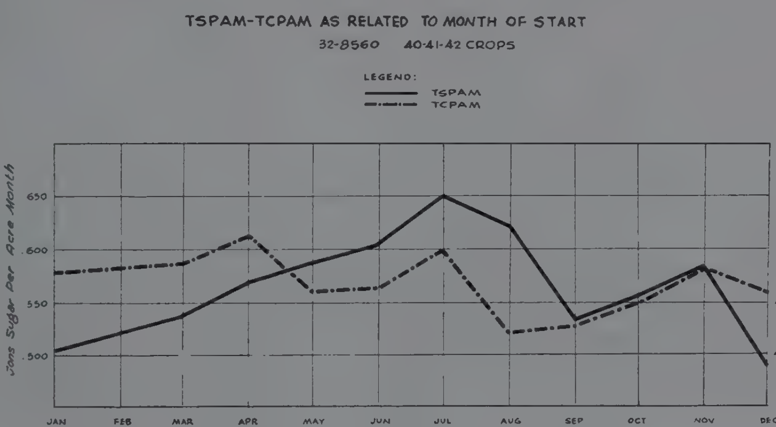

Fig. 2

three years. The greater proportions of these represent plant crops. There are insufficient data available for a study of ratoons as related to plant crop yields. For the purpose of this report, the plant and ratoon crops have been combined. Additional data will undoubtedly modify the trends shown in the following graphs.

Time of Start: Fig. 2 indicates the trend of 32–8560 yields as related to the month of start. It is shown on the basis of available information that April, May, June, July, and August have been the best months in which to start 32-8560 crops. The peak months occur in June, July, and August. It is surprising that the favorable months of start extend so far into the summer months. This is due, perhaps, to the lack of a substantial number of fields started in the early months of the year. There is a possibility that due to 32–8560's tendency toward rank growth, a midsummer start allows the crop to start well and at the same time puts two winter seasons and a growing summer in the proper place to exercise a favorable control on cane and sugar production. A similar control can also be afforded through fertilizer practice and irrigation control, at least in part. 32–8560 is able to sustain good growth

at lower temperatures than H 109 and the winter months do not constitute such a critical period of growth reduction. This can be noted in the graph on Average Weekly Growth (Fig. 1).

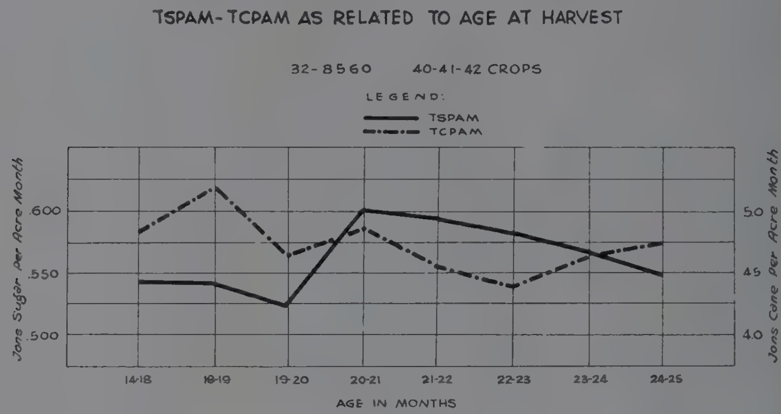

Fig. 3

Age to Harvest: Fig. 3 indicates the trends as to the proper age to harvest 32–8560 to obtain the best T.S.A.M. values.

This graph shows that the best age to crop 32–8560 is between 20 and 24 months. In this range of age, the most satisfactory sugar per acre month production came between the ages of 20 and 21 months. However, the manner in which sugar per acre month production is maintained up to 24 months points toward a 20–24-month cropping age as giving the best yields.

T.C.A.M. production is highest in the lower age groups and decreases gradually

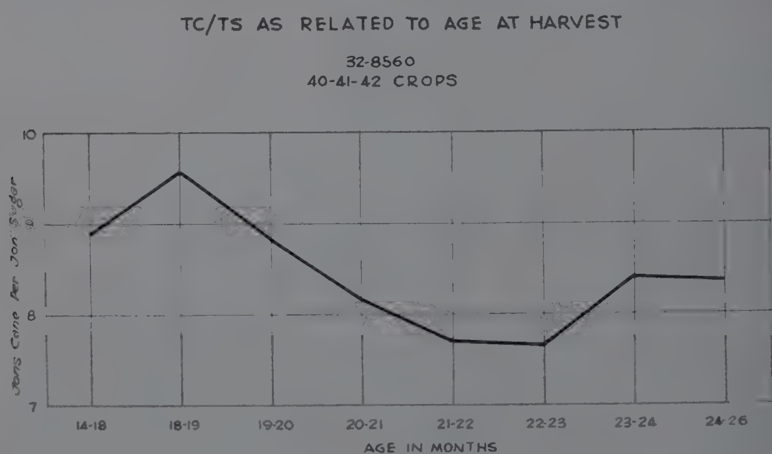

Fig. 4

with increased age, although beyond 24 months there is an indication of a rise in T.C.A.M. We have evidence that 32–8560 will carry over in good condition beyond 24 months if necessary; however, due to the decreasing rate of sugar per acre month production, it is felt that excessive age should be avoided if at all possible.

T.C./T.S. and Age at Harvest: On the basis of available data, juice quality appears to improve with age up to 23 months. A graph of this sort does not give the complete picture because the cropping, especially the month of harvest, has a dominant effect on juices obtained, other factors being equal. T.C./T.S. as related to age is set forth in Fig. 4.

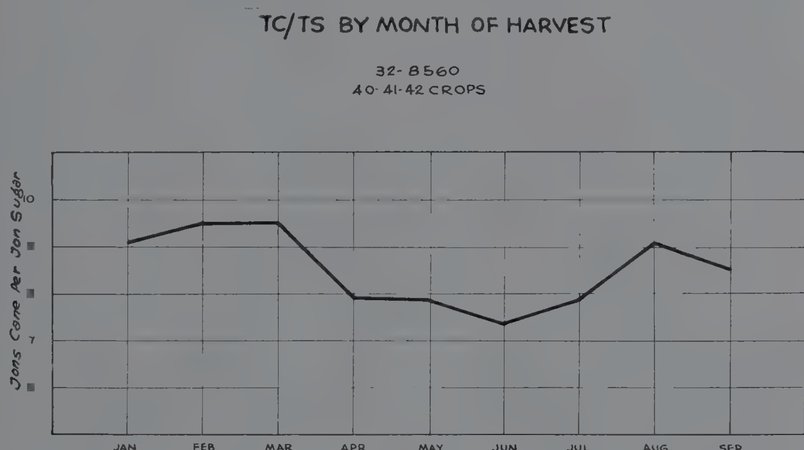

Fig. 5

T.C./T.S. by Month of Harvest: Fig. 5 sets forth trends in juice quality of 32–8560 as associated with month of harvest.

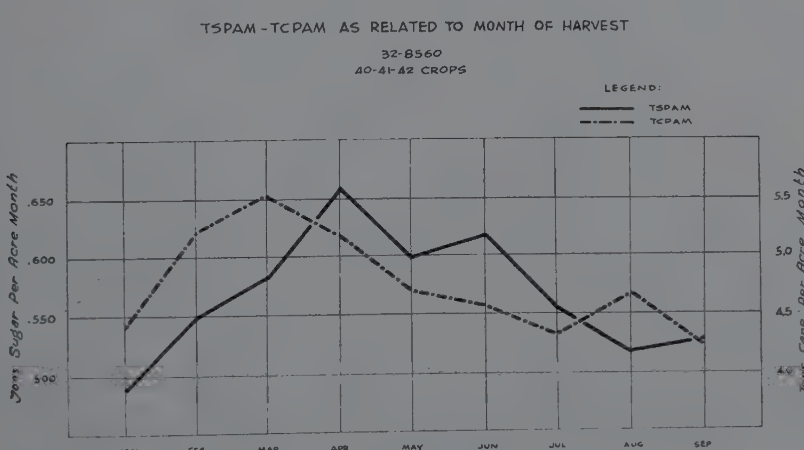

Fig. 6

Starting with March, juice quality steadily improves through June. In July there is a slight decrease in quality and in August, juices are somewhat poorer. The best juice months are April, May, June, and July.

Here again it is necessary to look beyond this graph to the others presented here. T.C./T.S. as related to age is a factor. Age at harvest is also a factor. In other words the combination of age and time of harvest influences considerably the quality of juice obtained.

Month of Harvest: Fig. 6 shows T.C.A.M. and T.S.A.M. as related to month of harvest for the variety 32–8560.

February, March, April, May, June, and July appea to be the best months in which to harvest for maximum sugar per acre month production. April, May, and June are the peak months. This trend is consistent with past experience.

Comments on Cropping:

It appears that 32–8560 does best when harvested between the ages of 20 and 24 months. Per acre month production decreases with increased age so crops should preferably be between 20 and 22 months of age; however, 32–8560 does well enough at 22–24 months to justify amply crops of that length. Since the best economic returns are not always associated with maximum sugar per acre month production, the carrying ability of 32–8560 in crops over 22 months of age is of definite interest.

On the basis of observations and yields, crops harvested late in the year (August, September, and October at Waialua) should be in the age range of 22 to 24 months for best results. This is a period of declining juice quality and 32–8560 which is a little older and with fewer immature stalks is better suited for harvest at this time than is a 20- to 22-month crop. Still younger cane harvested late in the season is even more dangerous.

If it is necessary to take short crops, it is felt that 14 to 16 months cane is more satisfactory than 16 to 19 months cane, particularly if the fields are to be harvested late. In the 14 to 16 months group, the suckers have not had time to develop to the point where juice quality is adversely affected to a serious extent. Fields 16 to 19 months of age harvested late at Waialua have given relatively poor yields compared with similarly aged fields harvested during the period from April to June. In general it is felt the short crops of 32–8560 should be avoided whenever possible.

32–8560—Diseases and Pests:

In addition to being a versatile variety in relation to soils, elevations and climate, 32–8560 is outstanding in its resistance to plant diseases and insect pests.

Plant Diseases: At Waialua no major plant disease has made a serious threat to the variety.

32–8560 has proved to be resistant to eyespot disease. This represents a real stride forward in disease control at Waialua. The use of a resistant variety has practically eliminated the presence of a disease that a few years ago was causing real financial loss to Waialua. This is an outstanding example of disease control by the use of a resistant variety.

Brown stripe has been observed, particularly in the mauka areas during the winter months when low temperatures and rainy weather dominate the environment. The extent of brown stripe during this period of the year has not been considered serious. 32–8560 can be considered rather tolerant to this disease.

Chlorotic streak, a potential pathological danger, has been observed in low poorly drained areas. Recently we have noted the disease in mauka areas where seed was taken from low poorly drained fields. As a precautionary measure we are trying to avoid the cutting of seed from such fields.

Due to the rank growth characteristics of the variety, a few scattered cases of knife-cut have been noted. Proliferation in ratoon stools has also been observed. Major plant diseases have been conspicuous by their absence and thus far have offered no problem in the growing of this variety.

Pests: Insect pests have not found 32–8560 to their liking. At least conditions have been such that damage has been minor for the period in which 32–8560 has been grown at Waialua.

Rat damage is, of course, chronic but as long as rat control measures are continued, there will be no threat from this source.

Armyworms have appeared on 32–8560; however, due to the prevalence of parasites in the district, we have had no epidemics of serious proportions. No other insect pests have caused damage on 32–8560 sufficient to recognize them as serious pests.

Milling Characteristics:

Among the newer varieties, 32–8560 resembles H 109 more closely in milling than any of the others. 32–8560 is harder on the knives. Tests have shown that the knife motors require more power when handling this variety. This is probably due to the long stringy fiber. Boiling house characteristics are about the same as H 109.

In the fireroom there is again a striking similarity between 32–8560 and H 109. Bagasse samples from this variety are usually lower in both moisture and pol than are most other varieties. It is felt that this may be, in part, due to the fact that practically all of the 32–8560 harvested through 1942 has been plant cane.

32–8560 has been observed to deteriorate more rapidly than H 109 after burning and harvesting. This has also been observed on other plantations. There is the feeling that this is largely due to the tendency of 32–8560 to split and tear rather than to have a clean break. Mechanical harvesting develops much cane that is in this condition. After rains, if the cane is slow in getting to the mill, there is usually considerable sour cane. To minimize the amount of deterioration, a close control on sizes of burns is needed. For that reason there should be close cooperation between the harvesting superintendent and the mill.

Harvesting Characteristics of 32–8560:

From a harvesting point of view, 32–8560 is more like H 109 than any other variety we have grown. H 109 in the harvesting field as in the mill is looked upon as the best cane to handle. The fact that 32–8560 comes very close to H 109 is fortunate.

Grab-harvesting has found the stools of 32–8560 to be strong, and they do not pull out excessively. Like H 109, 32–8560 will either break off at the surface of the ground or will leave a 3- to 5-foot stalk which can be readily handled by the ground crew. It is vastly superior to 31–2510, H 8965, 31–2347, P.O.J. 2878, 27–8101, 31–1389, 31–2806, and others that have come through the variety parade of the past years.

Due to the rank growth that develops with 32–8560, the quality of burns obtained

are usually not as good as with H 109. The persistent green tops generally never dry up and burn as well as does H 109. This results in a somewhat higher per cent trash with this variety.

With the present form of harvesting being used, 32–8560 seems well adapted to grab-harvesting due to its heavy tonnages.

The principal fact of interest is that this variety has no serious handicaps that affect its harvesting. It has been generally observed, due to its growth habit, that it can withstand more rigorous treatment than can, for example, H 109. With our present method of harvesting, this is of real importance.

A Summary of 32–8560 at Waialua:

The spreading of 32–8560 started in 1938 and increased in area with each succeeding year. Sixty-nine per cent of the present cultivated area is now planted with this variety.

Germination and subsequent stands of the variety have been good. In general, replant has been light. The variety offers no problems in cultivation at Waialua and indications are that ratoons will be cheaper than plant cane to cultivate.

Good irrigation is required to obtain maximum yields with 32–8560. There is evidence that ratoons will require careful irrigation to obtain comparable yields with plant cane.

Ripening is still an uncertain factor with 32–8560. Much care and study is needed to ripen 32–8560 effectively within the range of controllable factors. Further studies are being made.

Fertilization has been close to optimum. Recommendations for a nitrogen reduction in plant 32–8560 are made. It is suggested that this can be applied where needed in ratoon fields of the variety. Phosphate and potash practice appears to be satisfactory.

The growth rates of 32–8560 are shown to be considerably better than H 109. The interpretation of these growth data is of real importance in relation to cropping and cultural practices.

It is shown that 32–8560 gives its best yields in the mauka areas above 300 feet elevation. This refers to both actual yields and per cent gains over previous yields in the same fields. The mauka fields have displaced the makai areas for the time being, at least, as the most effective sugar-producing area at Waialua.

Lack of sufficient data makes a study of ratoon yields difficult at present. Suggestions for improved cultural practice in ratoons have been made.

Several graphs pertaining to factors affecting the cropping of 32–8560 are presented. Although based on averages, the data point out several trends which are of importance in effective cropping.

32–8560 has been found to be resistant to plant diseases and pests. Milling and harvesting characteristics of the variety are touched on briefly.

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Sugar Prices

96° CENTRIFUGALS FOR THE PERIOD
MARCH 15, 1943, TO JUNE 14, 1943

Date	Per pound	Per ton	Remarks
Mar. 15, 1943–June 14, 1943.........	3.74c	$74.80	Philippines

THE HAWAIIAN PLANTERS' RECORD

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